4-26-2009

Evaluating the impact of blade server and virtualization software technologies on the RIT Datacenter

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Virtual Infrastructure Administrator
Rochester Institute of Technology's Datacenter

Contact: chris.butler@rit.edu

Sustainable Development Class Project

March 2, 2009

Executive Summary

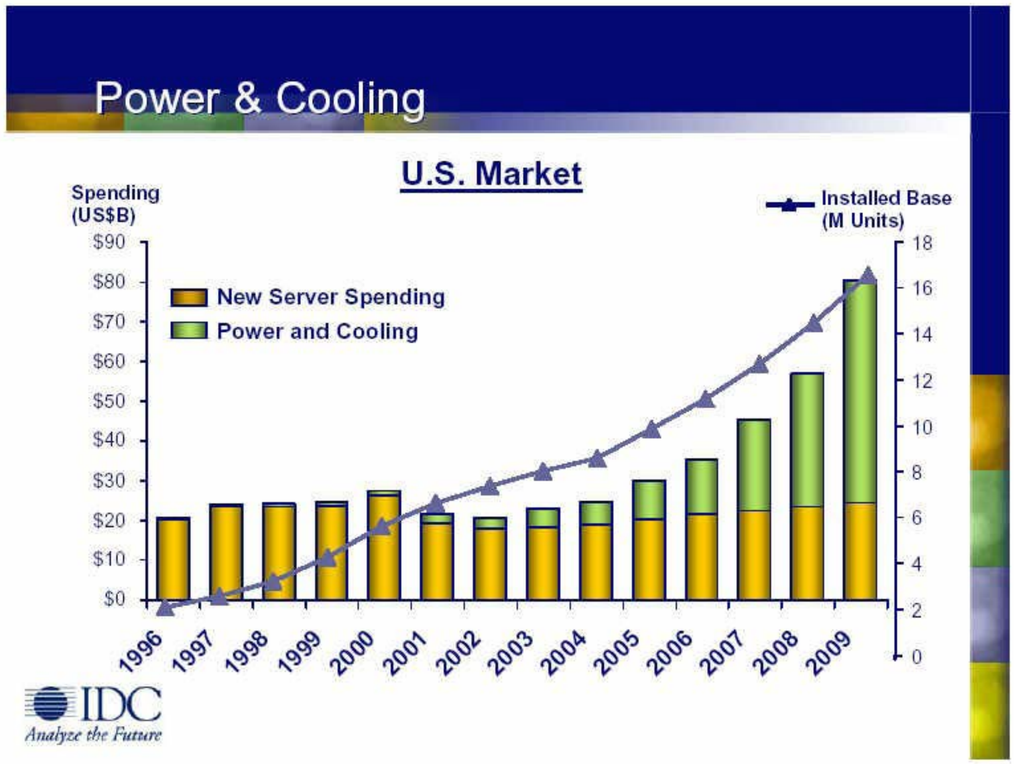
Over the past decade the cost to power and cool corporate Datacenters has grown dramatically (Figure ES 1). The expenditure for power and cooling has begun to exceed the annual capital expenditure of server hardware. This growth in power and cooling requirements is threatening the sustainability of current datacenter design. The current business practices, server processing capacity utilization rates, and cooling strategies surrounding datacenter operations need to be reevaluated in order to bring aging datacenters back into a sustainable business model.

This study takes a look at the existing server infrastructure of Rochester Institute of Technology's datacenter and provides recommendations for efficiency improvements. The recommendations are based on a detailed inventory of server hardware in the RIT datacenter and on observed hardware utilization rates. The potential improvements in efficiency are based on two trends in the IT industry which are to reduce space and power requirements using blade servers and to increase CPU processing utilization rates using server virtualization.

The expansion of computing services and resources is a fundamental activity in datacenters. Over time the isolation of these services for security and availability reasons has been accomplished through the operating system boundary. This model of isolation has led to an exponential growth in server hardware. To combat the energy costs due to the growth of IT services companies have utilized blade centers which place multiple individual servers into a single case where power, cooling, and network connectivity are shared. In order to reduce the amount of underutilized server hardware companies have leveraged server virtualization software which balances the load of individual operating systems across a cluster of physical servers. Hardware capacity can be added to meet new service demand without a disruption of service.

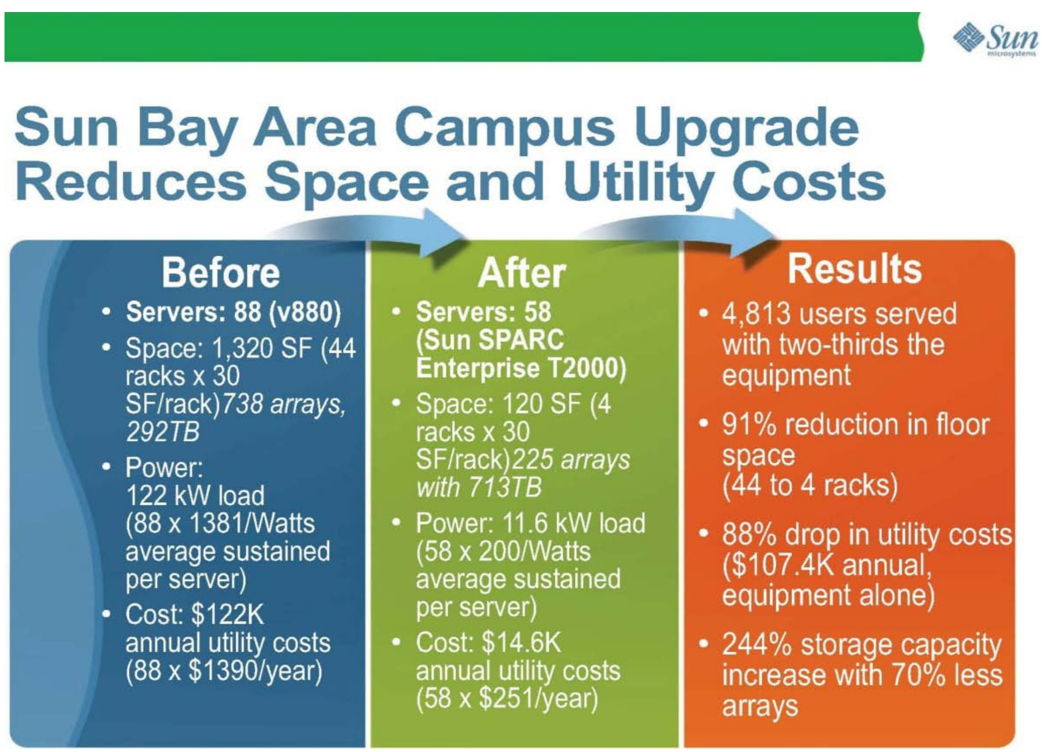
Many existing datacenters have seen dramatic reductions in operating and capital expense due to the improved efficiency of hardware and the increased utilization of that hardware. Sun has published the outcome of multiple datacenter consolidation projects outlining the process and the resulting cost savings (Figure ES 2). RIT has the potential to save millions of dollars over the next 5 to 10 years by strategically leveraging cost efficient technologies, scrutinizing existing hardware purchases for performance/watt ratings, and encouraging individual departments to consolidate server hardware into highly utilized central server clusters.

Figure ES 1: Server Power and Cooling in U.S. Market



(Geenrits)

Figure ES 2: Sun Server Consolidation Results



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Introduction

The Rochester Institute of Technology (RIT) datacenter houses 314 physical servers. These servers are owned and operated by multiple departments within RIT. The Information Technology Services (ITS) department manages 130 of these servers. Various individual colleges and departments rent rack space in the collocation area which is a segment of the datacenter where individually secured racks are provided to ITS customers for an annual charge. There are 80 servers in the collocation area managed by various departments. Another 104 servers in both the ITS operated area and the collocation area are operated by various departments and used for research focused computing. The remaining 130 servers are woned and operated by the central IT department (ITS). This study looks at the usage and characteristics of servers residing in the datacenter and makes recommendations for improved efficiency and reduced overall costs. The servers are grouped into ITS owned, collocation customer owned, and research computing focused.

Over the past two years the collocation area was created and sold to RIT departments. Many departments took the opportunity to leverage the large cooling and battery backed power (UPS) infrastructure of the datacenter. The quick migration of servers into the datacenter caused a dramatic increase to the load on the datacenter UPS. Today the load on the datacenter UPS is approaching 100% of its redundant capacity. Customers have additional servers that they plan to move into the collocation area but are being asked to wait until the power constraint is dealt with.

There are two likely scenarios to address the existing power constraint which is threatening the continued growth of the existing RIT datacenter. The first option will require a large UPS upgrade to expand the power capacity available for the continued increase in quantity of server hardware. The second option is to dramatically improve the efficiency of server hardware in the datacenter while continuing to increase computing capacity for years to come. The second option is more difficult than the first because it requires collaboration among the various colleges and divisions that own hardware in the RIT datacenter. It is my hope through this study to convince RIT's upper management to cover the cost of upgrading any department's hardware in the datacenter that is inefficiently consuming power. This could provide the incentive for all parties involved to work together toward a common goal of reducing excess waste of energy, continually expand the total computing capacity of the datacenter, and reduce the overall cost for computing at RIT.

Trends of U.S. Datacenter Energy Consumption

According to a study produced by Jonathan G. Koomey, Ph.D., based on data from IDC, Intel, IBM, Dell, and other sources, the average U.S. datacenter has experienced a 15% annual increase in power consumption due to a growth in the number of servers with only a small part of that growth from increased power consumption per unit (Jonathan G. Koomey, 2007). Data directly from IDC charts confirm this growth in power consumption (Figure 1- Datacenter total electric use by U.S. and world datacenters, Figure 2 - U.S. Datacenter Power & Cooling Trend). A solution to the continued growth in electric power consumption is to improve utilization rates of hardware and to refresh the server hardware when the performance/watt ratio of older servers falls too far behind the performance/watt ratio of the latest server hardware.

Methodology

This study audits the datacenter servers and attempts to analyze the server hardware for utilization rates and for performance comparison through the use of Standard Performance Evaluation Corporation (SPEC.org) CPU benchmarks. Each model of server in the datacenter was given a projected CPU performance rating based on benchmark results published through the SPEC.org SPECint_rate2000 and SPECint_rate2006 benchmark suites. The average CPU utilization rate of ITS servers was gathered through historical CPU usage data in ITS's server monitoring software (Hobbit) and applied as an average to the collocation customer servers. The computing cluster server utilization rate was based on a worst case load given by the research computing system administrator. These findings provided enough information to project required blade server hardware at a continuous 80% CPU utilization using VMware's enterprise virtualization software (ESX) based on current total CPU capacity in the datacenter based on CPU integer processing rate benchmarks.

Annual hardware costs for new HP blade servers were based on current HP blade server hardware pricing (Table 2 - HP Blade Server Pricing (January 2009)). Estimates for existing server costs were based on lowest average server pricing per focus group; $2000/research compute node, $4000/server in Collocation area and ITS owned servers. The $4000/server estimate is a low estimate when considering the expense of larger multiprocessor servers in the datacenter whose initial cost exceeded $25,000/unit.

Electric costs were based on RIT's current $0.07/KWh as reported by Catherine Ahern, director of engineering services at RIT's facilities management department. The electric cost was used to calculate electricity costs for servers based on rack power monitoring and from the datacenter UPS report on current input and output KVA (Table 4 - Rack Power Observations).

Power and cooling estimates were based from various tools and observations. HP's blade system power sizing tool (Table 3 - HP BladeSystem Power Sizing Tool v3.7.1) was used to calculate power (watts) and thermal load (BTU) of blade servers running at 80%. Industry standard formulas for power and cooling calculations (Calculations and Costs) were used to estimate changes in power consumption of servers (watts) and the resulting cost to cool the thermal load from servers (BTUs).

Scope

The scope of this study is to evaluate the existing servers in the datacenter and attempt to calculate 5 to 10 year projections for power, cooling, and CPU performance for the continuation of current server usage trends. The same 5 to 10 year projections were used to look at potential power, cooling, and CPU performance in the datacenter if all servers were virtualized and run on HP blade servers. There are specific applications that require special CPU architectures that may not work in a HP blade server environment. My assumption regarding this exception is that it is less than 1% of existing services. This study considers factors like special grants and donations to be out of scope for the projections. In addition, the storage hardware and network infrastructure were also considered out of scope due to the enormity of combining multiple virtualization projects into one study. Whenever estimates were used the results erred on the conservative side to provide worst case benefit scenarios.

Findings

Calculations and projections for consolidation of hardware in each area of focus were performed separately and also in combination. The same variables were used across all area predictions except for the initial data collected through observation.

Research Computing Hardware

Research computing servers in the datacenter have characteristics that set them apart from the ITS and collocation customer servers. The research computing servers were typically running between 60% and 90% utilization which according to Sun (Figure 3 - Energy Waste at Low Utilization) is within the range of efficient usage of processing power versus electric use. The calculations and findings for research computing are included at the end of the appendix section. The cost benefit for consolidating research computing hardware on HP blade system hardware did not provide a return on investment in the first 5 years of projections.

ITS Servers

The ITS servers are centrally monitored for CPU usage and have detailed inventory information available for use by this study. The accuracy and amount of data available for estimating CPU usage provided an average CPU utilization rate of 12%. That underutilization of hardware is an underlying cause for excess power consumption and inflated capital expense over time.

The ITS owned server hardware had a higher percentage of older hardware compared to research computing or collocation customers. Replacement and virtualization of this hardware could yield significant reductions in power and cooling costs over the next 12 months and alleviate the need to replace or expand the existing uninterrupted power supplies in the datacenter.

Collocation Customer Servers

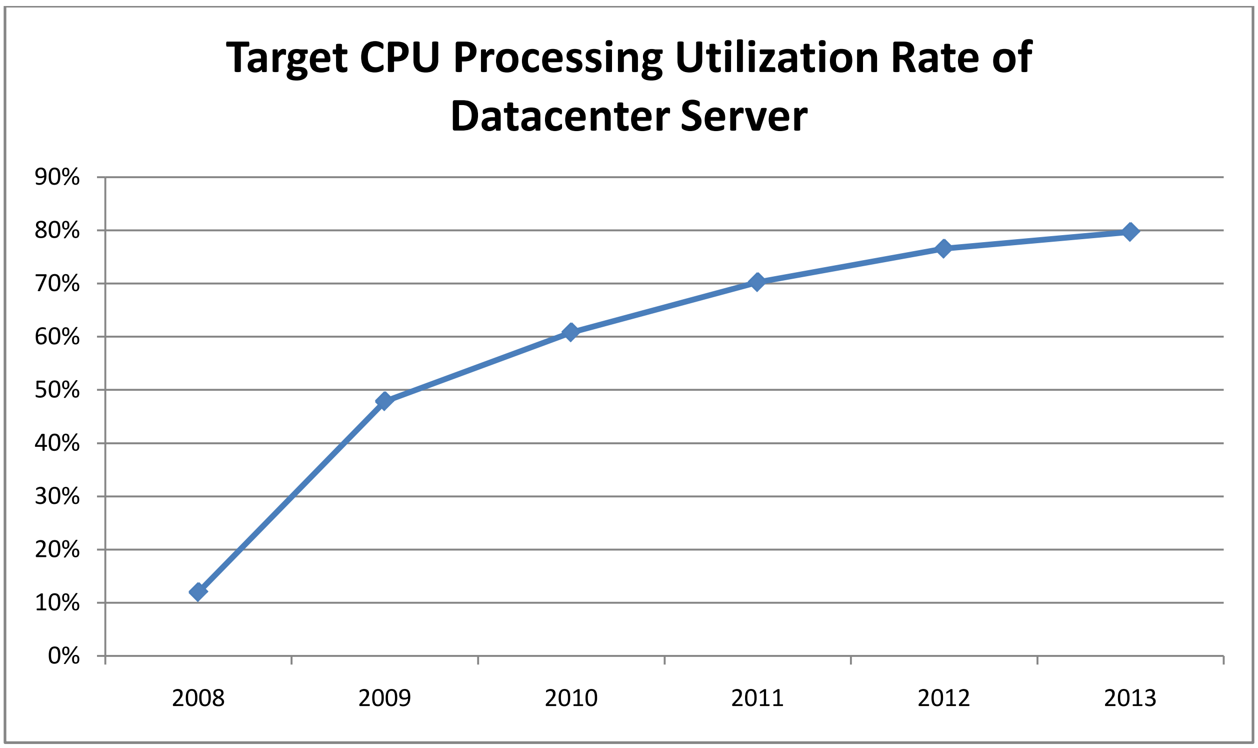
The servers in the collocation area are of similar nature to the ITS owned hardware. The range of CPU performance was identical to the range found in ITS servers. Without direct access to monitoring data the CPU utilization rates were estimated to be similar to ITS's server hardware.

Results

The following graphs were generated from data collected and analyzed during the study. The tabulated data for the graphs can be found in the appendix.

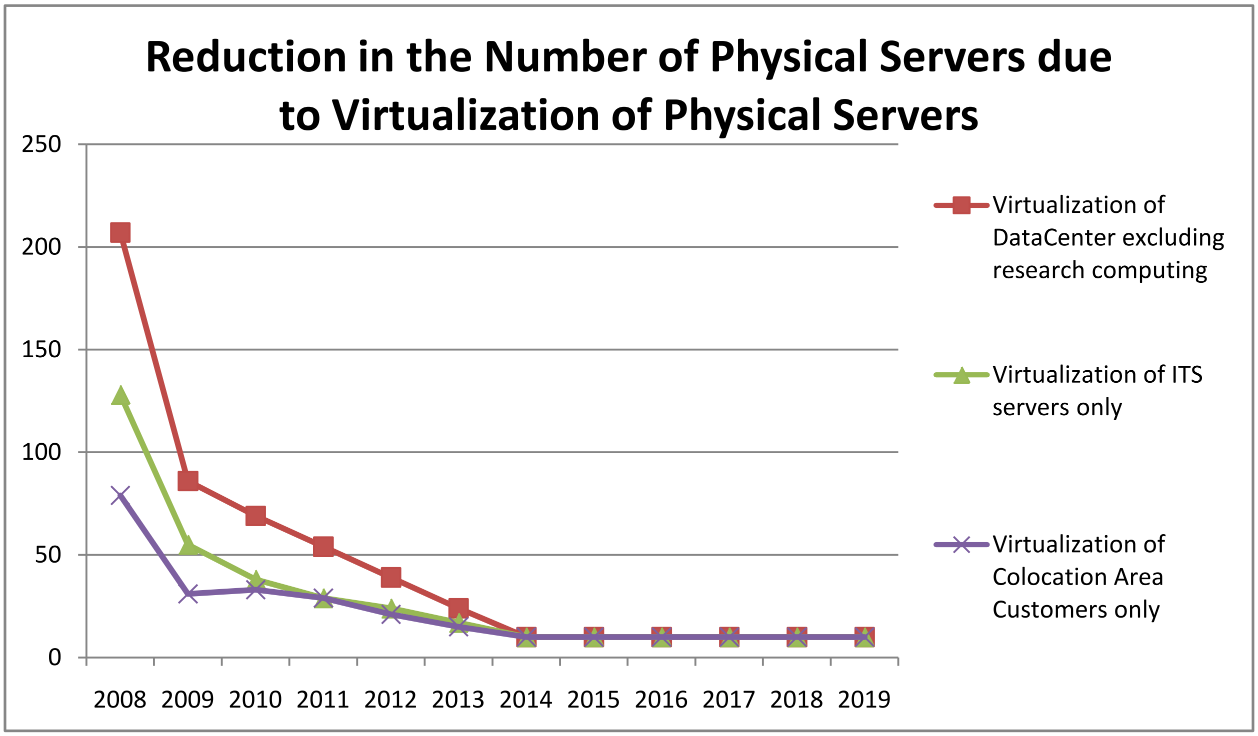
Target CPU Processing Utilization Rate of Datacenter Server

This graph shows the projected level of server utilization resulting from the migration of individual servers to HP blade servers running VMware's ESX virtualization software. The migration of existing servers will take approximately 1 hour of service outage and will need to be scheduled with the service owner. Existing servers with excessive amounts of data will take up to 4 hours to migrate.



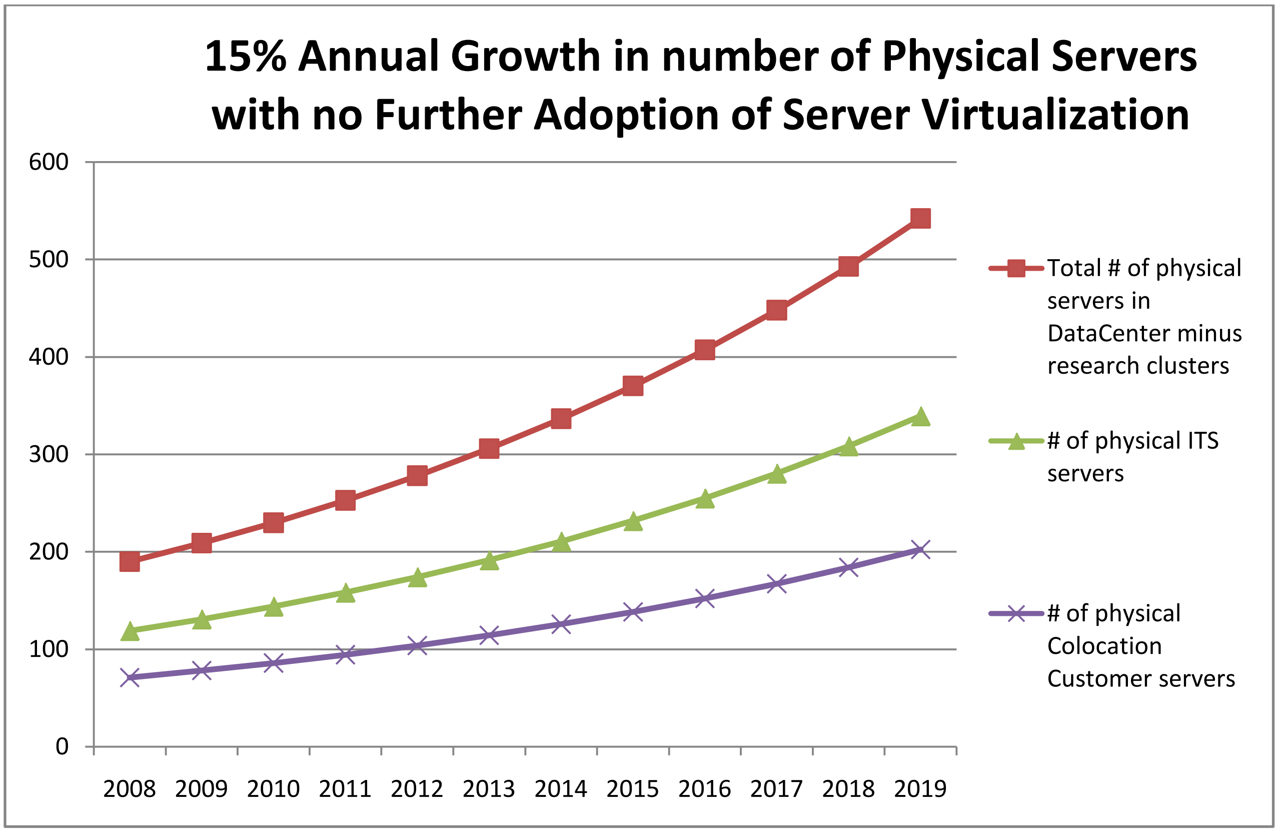
Reduction in the Number of Physical Servers due to Virtualization

This graph shows annual reduction of physical servers owned by ITS and collocation customers. After all standalone hardware is replaced in 2013 there will approximately 10 HP blade servers with enough memory and CPU processing power for all production services in the datacenter. Two additional blade servers may be required for test and development resources. The HP blade server chassis can hold 16 physical servers and has a 12 year support life from HP.



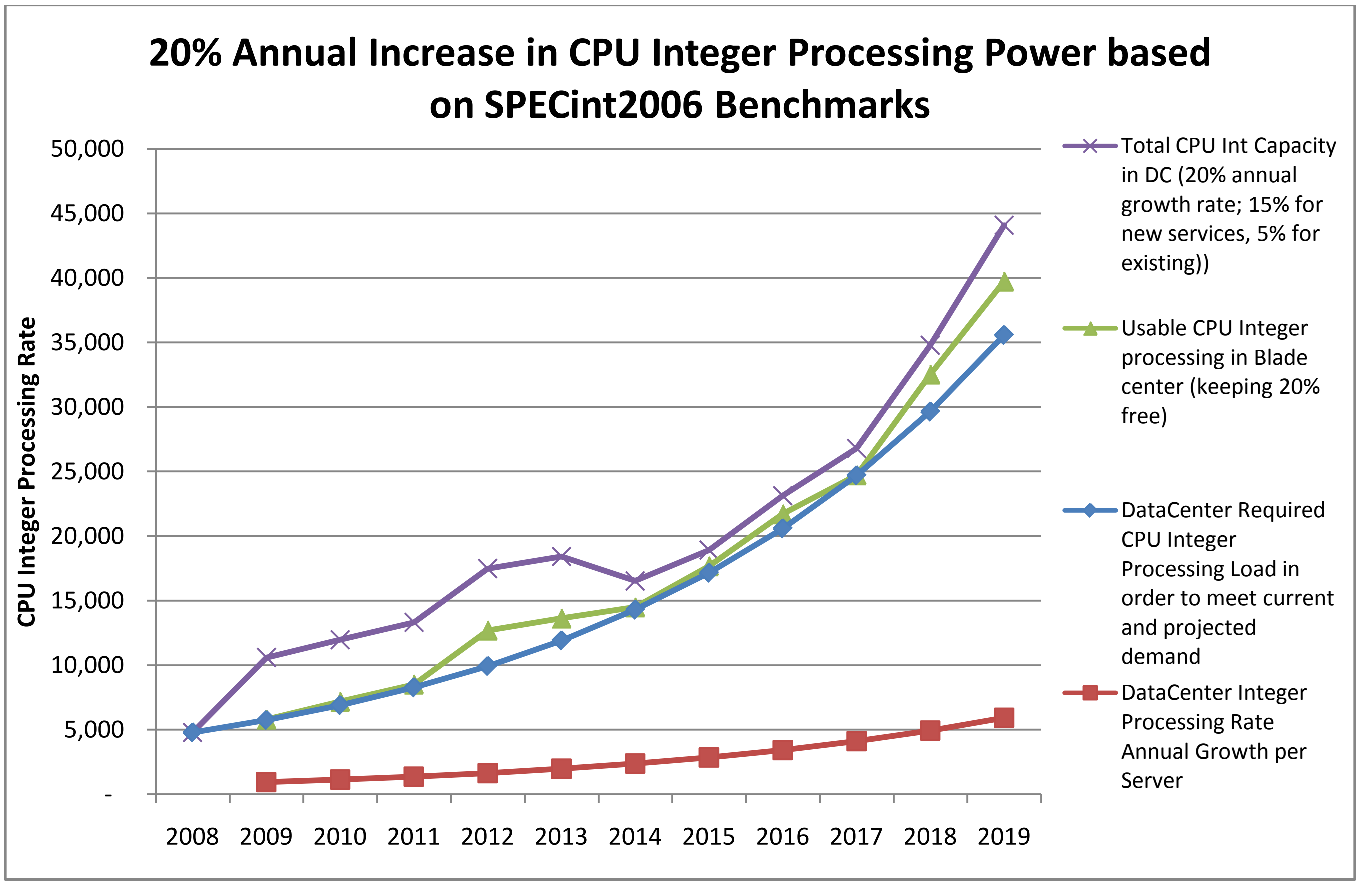
15% Annual Growth in number of Physical Servers with no Further Adoption of Server Virtualization

This graph shows the projected number of physical servers in the datacenter if there is no concerted effort to improve resource utilization. The 15% annual growth is based on IDC data (Figure 2 - U.S. Datacenter Power & Cooling Trend). ITS is currently using VMware and Sun Solaris virtualization technologies to reduce the number of physical servers. 37% of the services managed by ITS are run in virtual servers. Even with the higher level of hardware utilization on the ITS servers running virtualization software ITS has a total average utilization rate of 12% of existing CPU processing capacity. Improving the utilization of CPU power to a minimum of 60% would boast a dramatic reduction in physical servers, capital expense, and electricity consumption (Figure 3 - Energy Waste at Low Utilization).



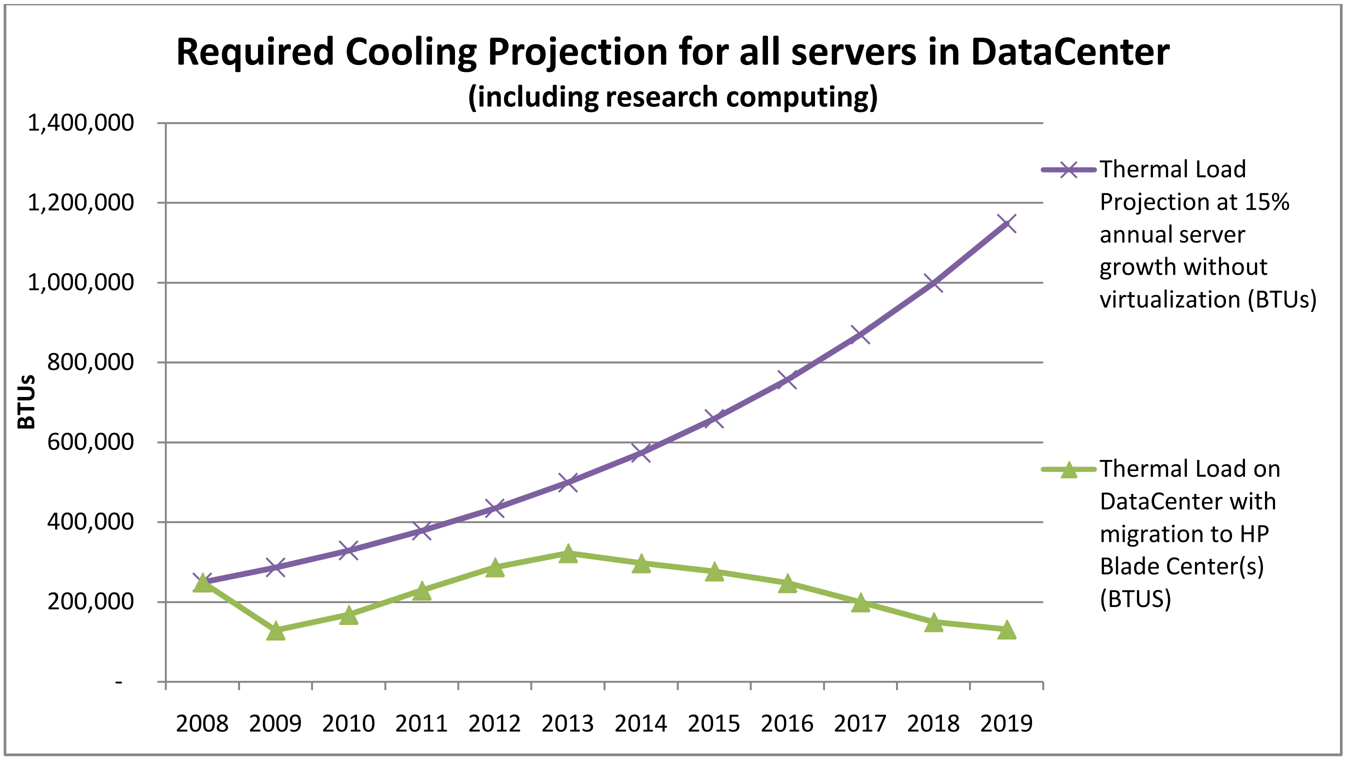
20% Annual Increase in CPU Integer Processing Power (Based on SPECint2006 Benchmarks)

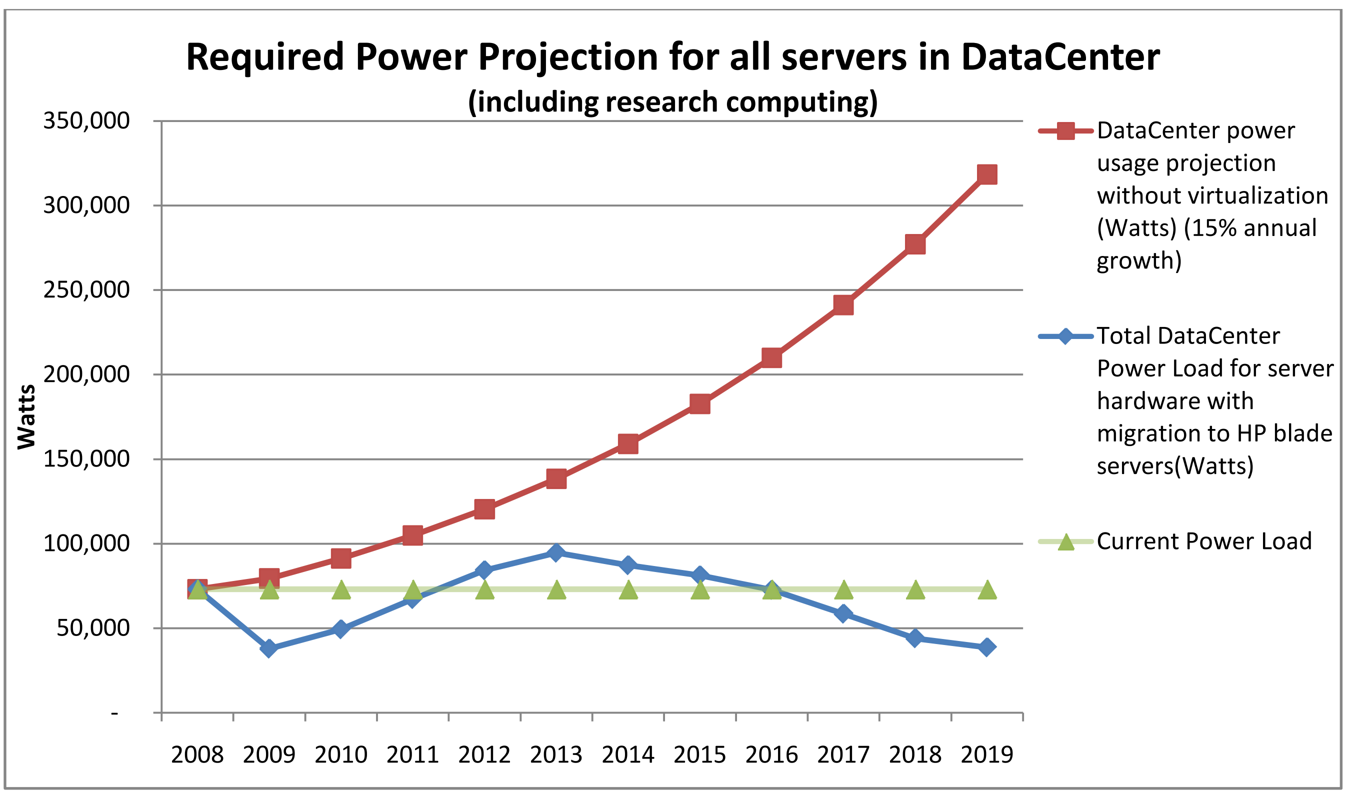
This graph shows the required CPU processing power for ITS and collocation customer services. The growth rate assumes a 15% annual growth in new services and a 5% annual growth in existing services. The bottom red line represents the CPU processing power of a single blade server purchased in a particular year. The smooth blue line represents the minimum required CPU processing capacity based on current hardware utilization and a 20% annual growth rate. The green line represents 80% of the total available CPU processing power of ITS and collocation customer hardware after the annual removal of 4-5 year old hardware. The top purple line represents the total available CPU processing power for ITS and collocation customer services.



Required Power and Cooling Projection for all servers in Datacenter (including research computing)

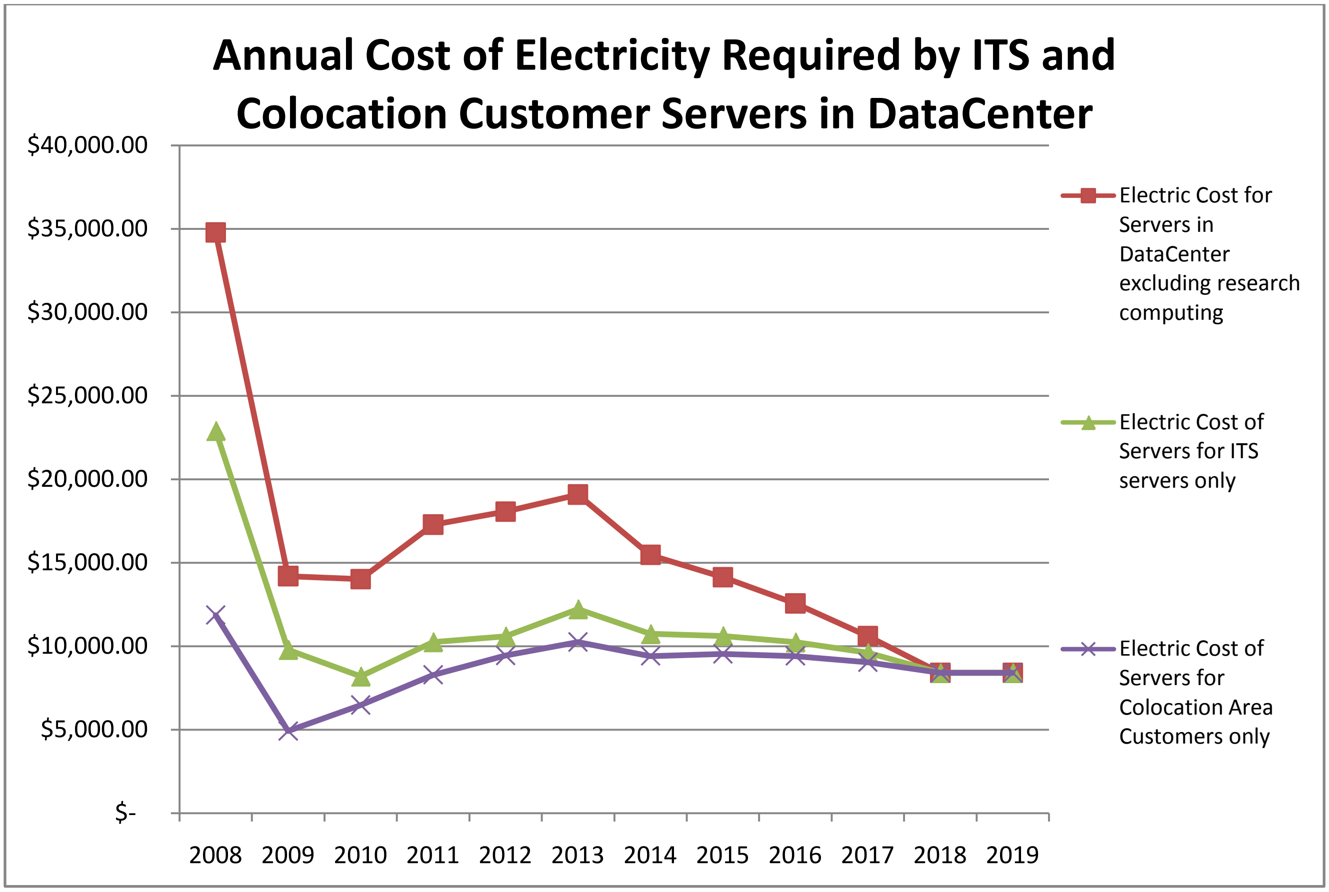
These graphs show the potential reduction in power and cooling resulting in better hardware utilization.





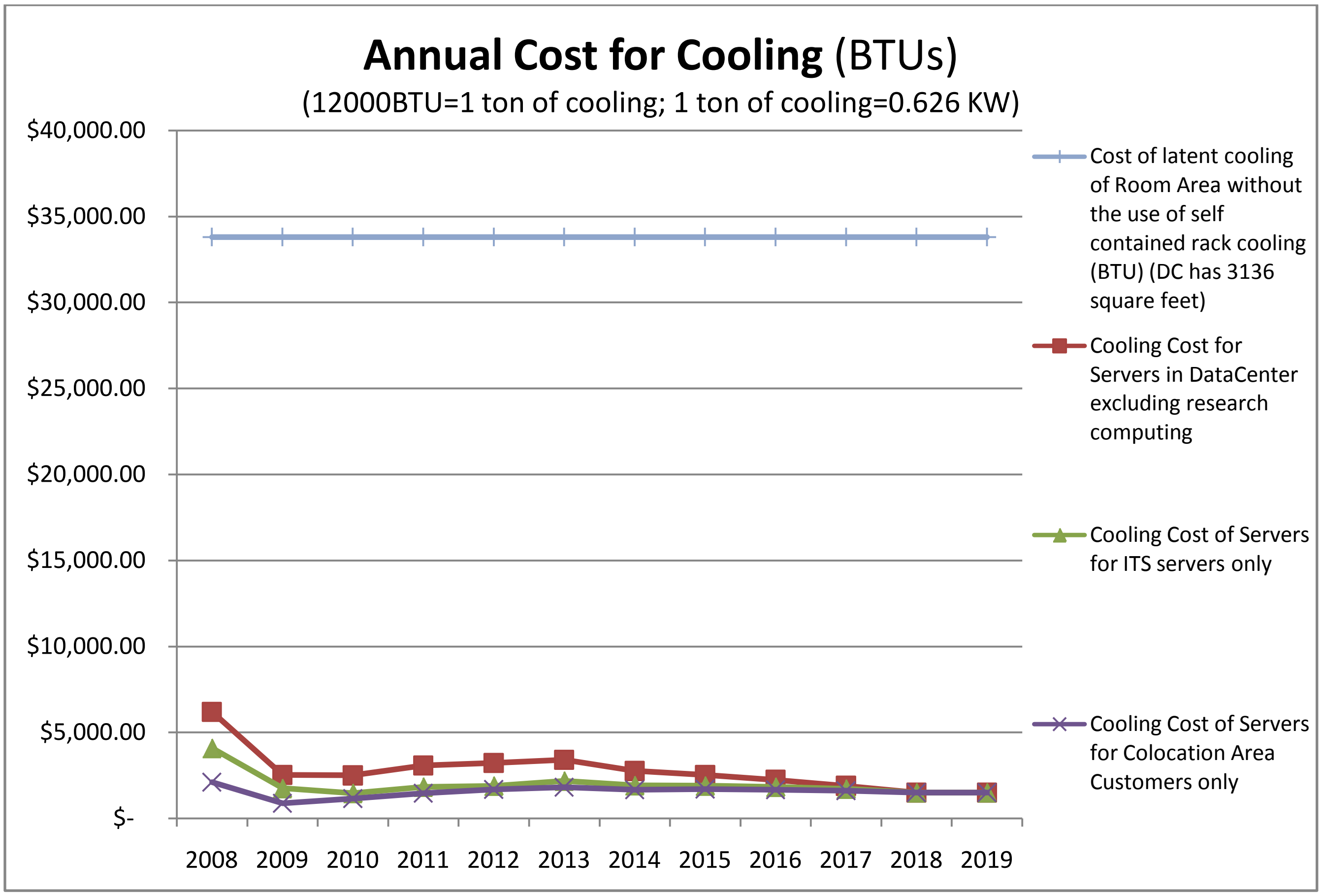
Annual Cost of Electricity Required by ITS and Collocation Customer Servers in Datacenter

This graph shows the cost for the electricity required to power ITS and collocation customer servers. The 2008 data is based on observed power usage from server racks with power strips that monitor amperage load. For servers without observable amperage readings the electricity was based on 50% of maximum non-redundant power supply ratings.



Annual Cost for Cooling

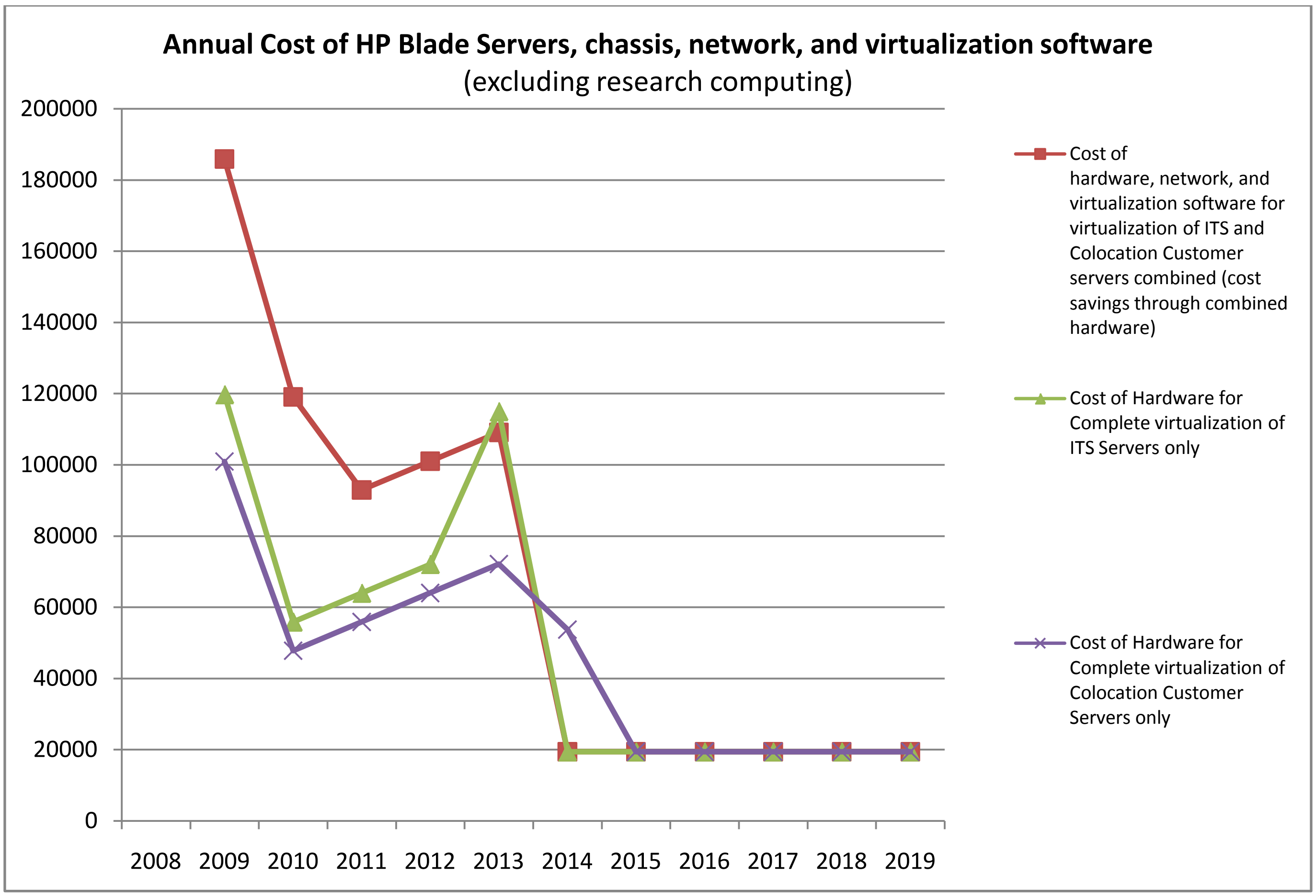
This graph shows the cost for electricity used to cool the datacenter volume of air (constant blue line) and the heat generated by physical servers. The cost estimates are based on RIT's current electricity cost of $.07/KWh and on power requirements for average Liebert air chilling units. The existing Liebert chillers in RIT's datacenter leverage passive cooling from outside air when outside temperatures are below 45 degrees Fahrenheit. Without passive cooling from outside air the chillers would require 1KW of electricity for every ton of cooling required. There is a 81.74% reduction in electricity used by the Liebert chillers when the outside temperature is below 45 degrees. The estimated power required for 1 ton of cooling capacity is 0.626KW based on average monthly minimum and maximum temperatures in Rochester.



NORMALS	1961-90	YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
ROCHESTER	Max	30	30.9	32.5	42.7	55.9	67.8	75.8	80.7	78.1	71.8	60.5	47.8	35.8	**56.7**
ROCHESTER	Min	30	16.3	16.6	25.7	35.9	46.3	54.3	59.6	57.8	51.7	41.6	33.3	22.4	**38.5**
Wattage needed for 1 Ton of cooling:			**183**	**183**	**183**	**800**	**1000**	**1000**	**1000**	**1000**	**1000**	**800**	**183**	**183**	**626.25**
http://www.met.utah.edu/jhorel/html/wx/climate/mintemp.html															

Annual Cost of HP Blade Servers, chassis, network, and virtualization software
(Excluding research computing)

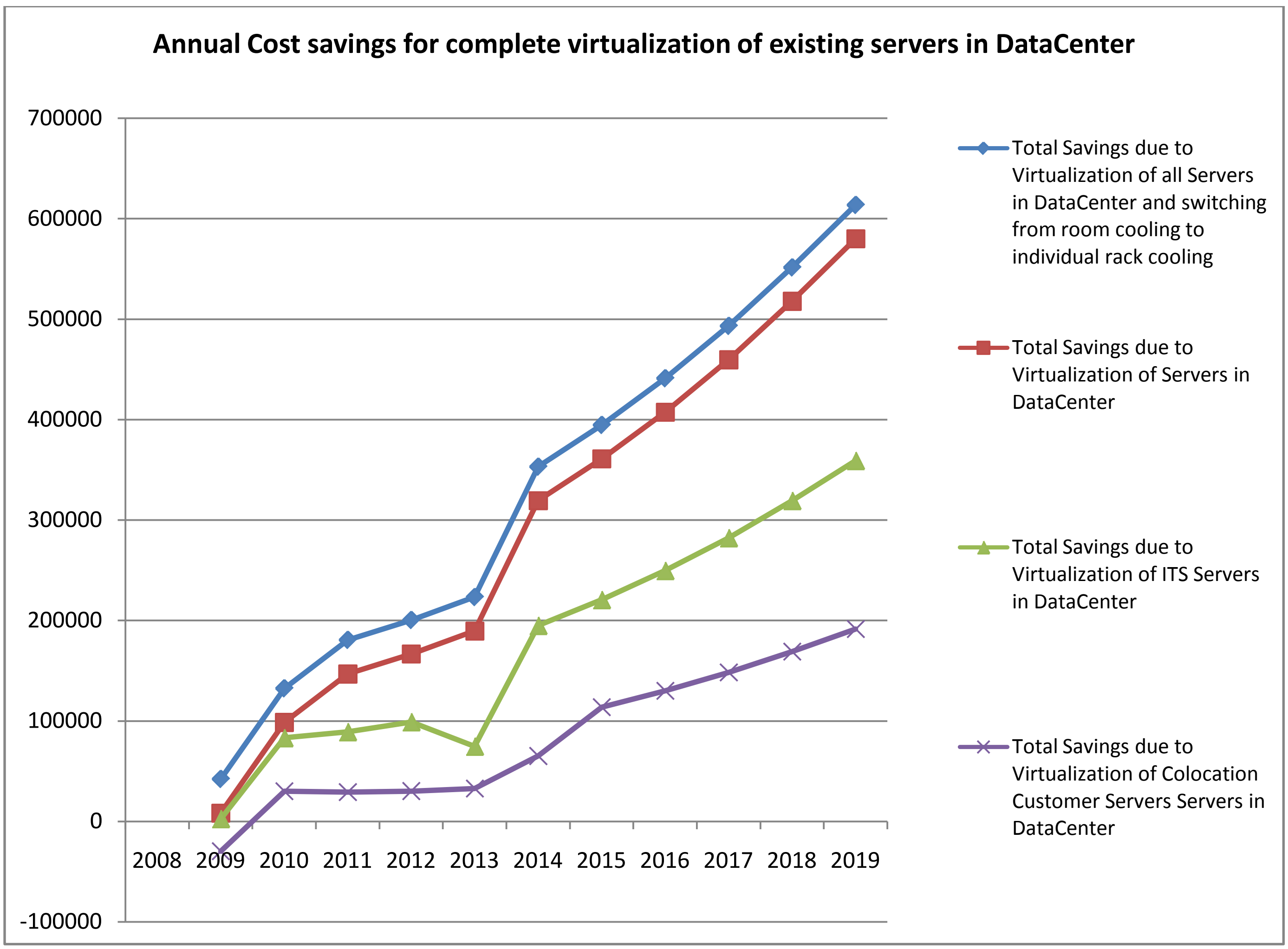
This graph shows the annual expenditure required for adding HP blade server hardware, network connectivity, and VMware's virtual datacenter software. The annual cost after 2013 drops dramatically after all older stand alone servers are removed from the datacenter. The projected costs include replacement of blade server hardware that is 5 years old. The ongoing costs from 2014 to 2019 are from the annual replacement of 20% of the HP blade server hardware, from hardware maintenance, and from software maintenance contracts. The HP Blade System chassis has a supported life of 12 years and an internal communication capacity of 5Tb/s which is adequate for the next 10 years of datacenter service growth.



Annual Cost savings for complete virtualization of existing servers in DataCenter

This graph shows the projected annual cost savings resulting from 100% virtualization of production services owned by ITS and collocation customers. The cost savings include the annual reduction in cooling and power requirements of server hardware. The cost of new HP blade server hardware, network connectivity, VMware virtualization software, and maintenance contracts are compared to the cost of individual server purchases at an average server cost of $4000 (without recurring maintenance costs) and an annual growth of 15% in new server hardware (based on IDC data).

In the next 12 months there is a projected net cost benefit of $8,000 through the removal of any server hardware that is 5+ years old. A total net savings of $609,998 is projected over the next 5 years and a net savings of $3,254,756 is projected over the next 10 years. These estimates are very conservative numbers and do not include the potential cost savings from not upgrading the current datacenter power infrastructure, from the reduction of network hardware, or from the consolidation of multiple storage area networks (SANs) in to a single virtualized storage environment.



Conclusions

The potential cost savings to RIT for increasing utilization rates of servers in the datacenter, decreasing power consumption, and providing a sustainable computing infrastructure is significant. I am estimating a complete return on initial investment by the end of 12 months after implementation when factoring in the cooling and electric costs. The estimated net savings over 5 years is $609,998. The estimated net savings over 10 years is $3,254,756. These estimates do not account for further savings through the reduction in the number of network ports in use by ITS and collocation customers from 527 (1Gb) ports to 4 (10GbE) ports. Further savings can be accomplished by changing the approach to cooling in the datacenter from four large 10-30 ton chillers to a single rack with self contained cooling. This reduces the amount of latent heat energy that must be cooled in a room containing 3,136 square feet of rack space and ambient air down to a single rack with 8 square feet of internal area. This reduction in air volume equates to a reduction of 1,056,832 BTUs of latent heat energy. (Imagine putting a large window air conditioner in your attic at home and hoping that it passively cools the rest of the house).

Further study can be made to improve the accuracy of these predictions. An audit of all server hardware purchases at RIT over the past 5 years would provide a more accurate growth rate of server hardware and a more accurate estimate of unit pricing. The $4000 per unit estimate in the study is assumed to be on the low side when factoring in the number of large and expensive servers in the datacenter.

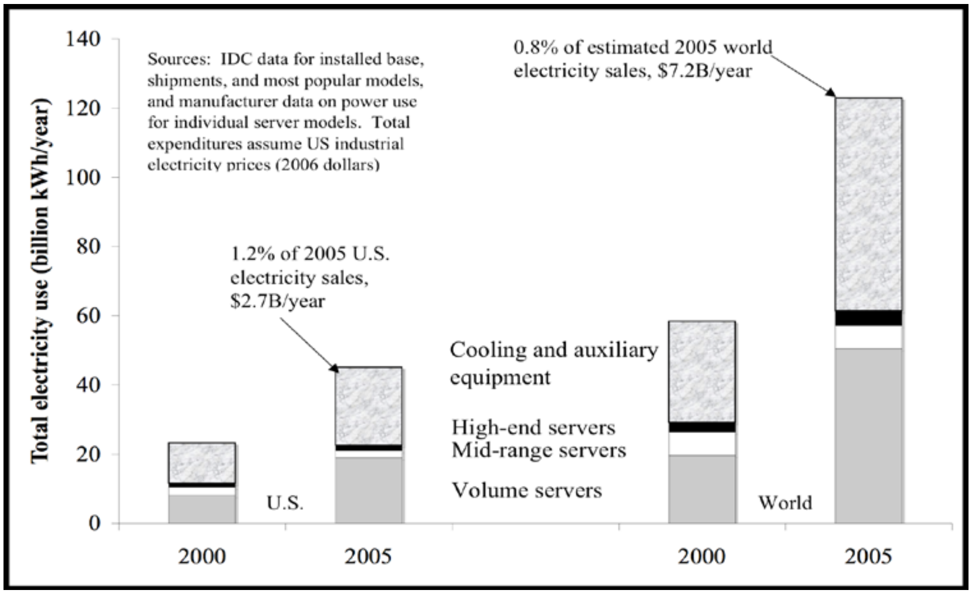
In summary I find the potential for cost savings and reduction of environmental impacts to warrant an improvement in hardware utilization rates in the datacenter. I urge that all server purchases are evaluated on a performance per watt basis. The current 5 year lifespan expectancy of server hardware is costing RIT more in electricity than it is saving in capital expense. A 5 to 6 year old server is approximately 8 times slower than a new server at the same initial cost. I would like to see a maximum of 4 years of production use for server hardware with the possible 5^{th} year for test and development use. At the end of 5 years the server hardware should be recycled.

I hope the findings of this report help to justify immediate action. The potential for savings is worth pursuing for at least 1 to 2 years to verify the accuracy of the projections. At worst the attempt to migrate toward a 100% virtualized infrastructure can stave off the cost of replacing the existing UPS hardware.

Appendix

Figures

Figure 1- Datacenter total electric use by U.S. and world datacenters



(Jonathan G. Koomey, 2007)

Figure 2 - U.S. Datacenter Power & Cooling Trend

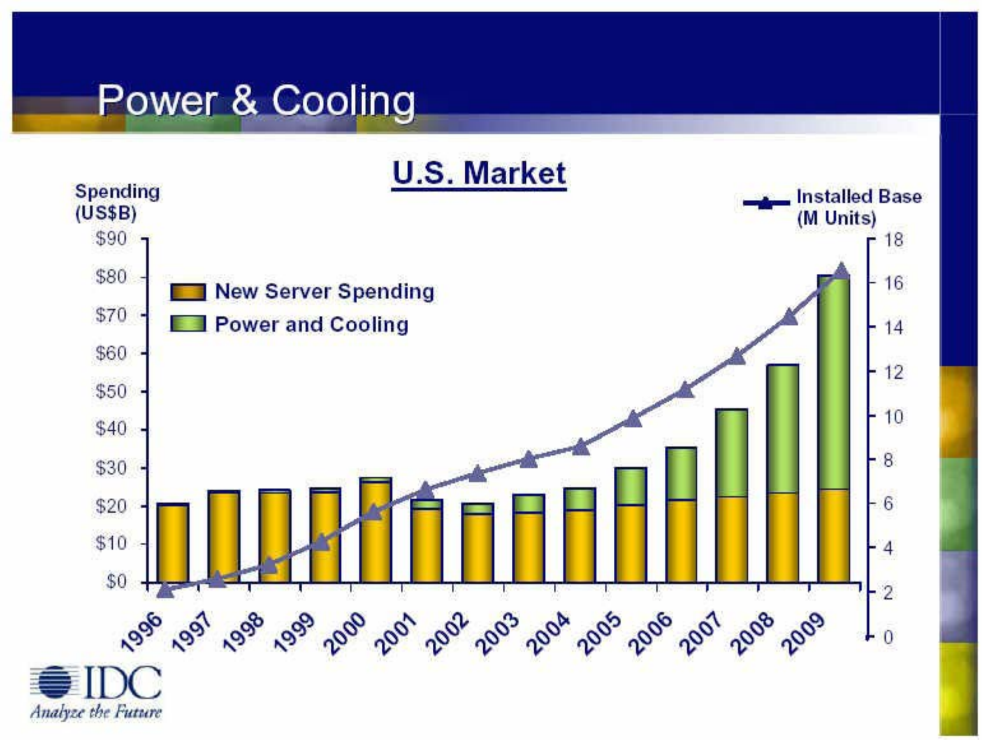


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Figure 3 - Energy Waste at Low Utilization

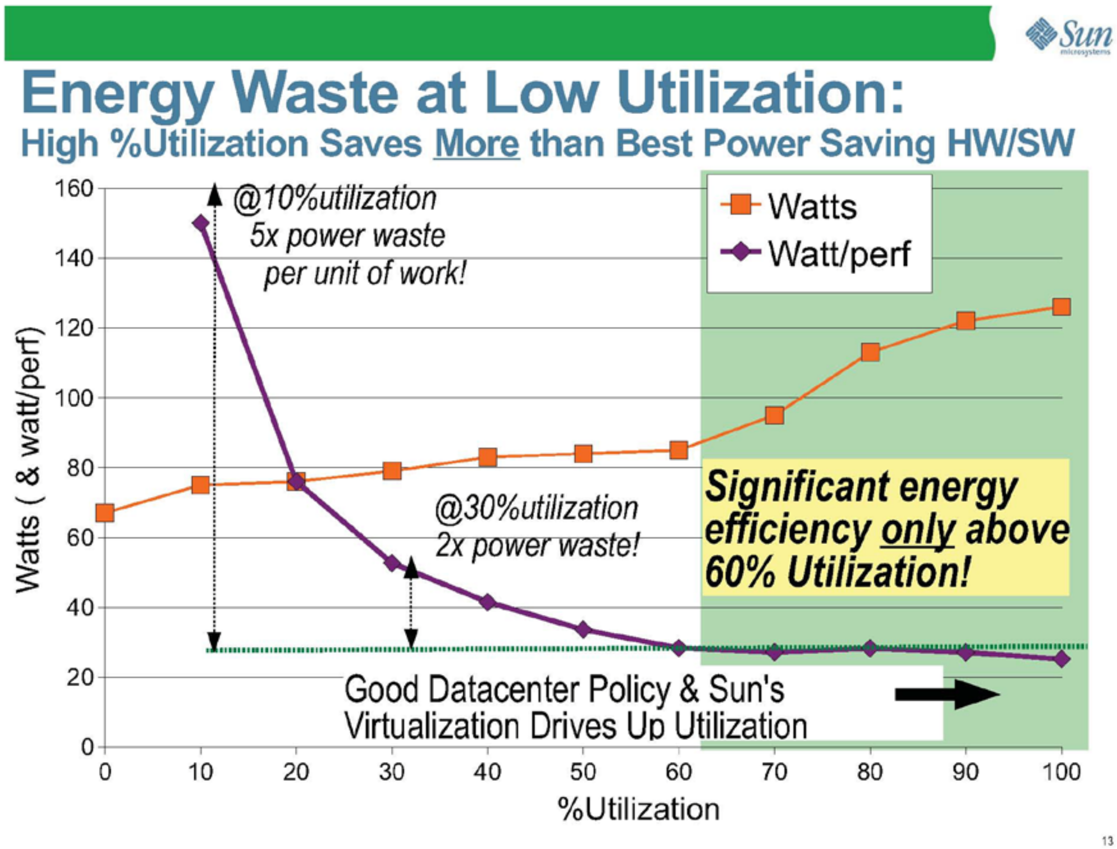

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Figure 4 - CPU Integer Processing Rate Per Watt

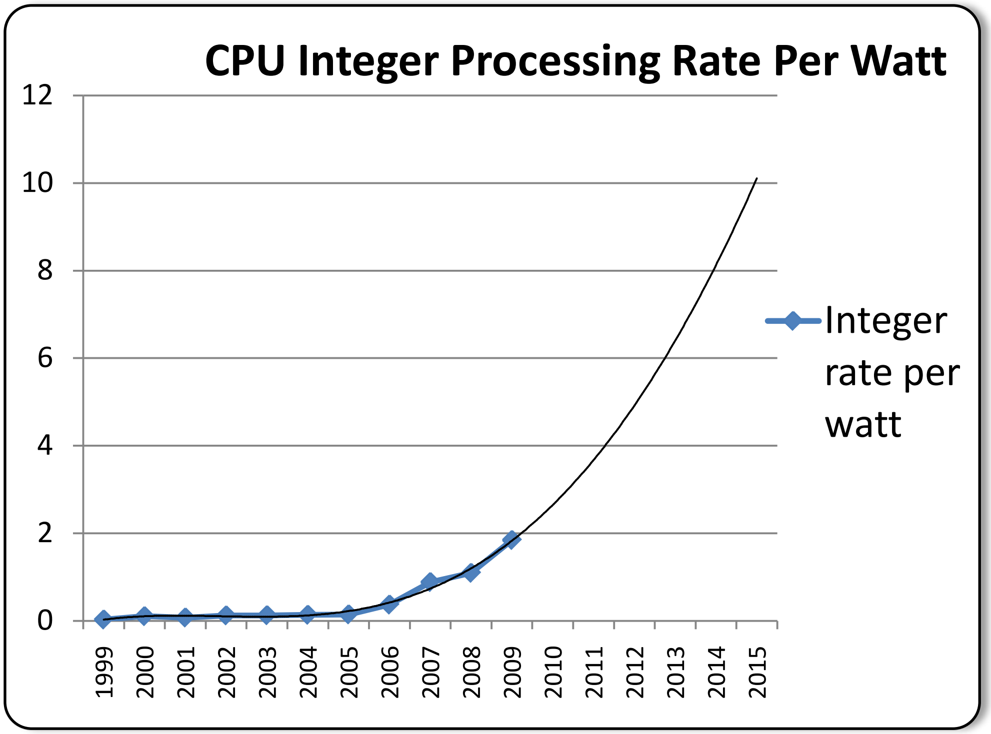

Table 1- CPU Integer Processing Rate Per Watt

year	Intel Xeon Processor	SPEC INT Benchmark	Power (W)	Integer rate per watt
1999	Pentium II Xeon 450	1.2	42.8	0.028037383
2000	Pentium III Xeon 866	3.1	29.6	0.10472973
2001	Xeon 1.5	4.4	59.2	0.074324324
2002	Xeon 2.2	7.5	61	0.12295082
2003	Xeon 3.06	11	87	0.126436782
2004	Xeon 3.2	14	103	0.13592233
2005	Xeon 3.4	16	110	0.145454545
2006	Dual-Core Xeon 5150	48	130	0.369230769
2007	Quad-Core Xeon X3230	84	95	0.884210526
2008	Quad-Core Xeon X3370	104	95	1.094736842
2009	Six-Core Xeon L7455	120	65	1.846153846

http://en.wikipedia.org/wiki/List_of_Intel_Xeon_microprocessors

Table 2 - HP Blade Server Pricing (January 2009)

Qty	Part #	Description	Unit Price	Ext. Price
1	412152-B22	HP BLc7000 CTO 3 IN LCD Encl	$ 3,492.00	$ 3,492.00
4	499243-B21	HP BLc7000 2400W High Efficiency Power Supply	$ 190.00	$ 760.00
6	412140-B21	HP BLc Encl Single Fan Option	$ 114.00	$ 684.00
2	413379-B21	HP BLc7000 1 PH FIO Power Module Opt	$ 129.00	$ 258.00
4	Opt. 7FX	c7000 Enclosure HW Supp	$ 562.00	$ 2,248.00
4	455886-B21	HP BladeSystem c-Class 10Gb Long Range Small Form-Factor Pluggable Option	$ 2,635.00	$ 10,540.00
2	455880-B21	HP BLc VC Flex-10 Enet Module Opt	$ 9,271.00	$ 18,542.00
15	454314-B21	HP BL495c G5 CTO Blade	$ 5,254.00	$ 78,810.00
15	UK068E	HP 4y Nbd BL4xxc Svr Bld HW Support Complex 1	$ 135.88	$ 2,038.20
15		Vmware ESX licenses w/ 4yr maintenance	$ 6,300.00	$ 94,500.00
		Total		$ 211,872.20
		Individual Blade Cost		$ 13,242.01

Table 3 - HP BladeSystem Power Sizing Tool v3.7.1

Power/Heat Load @ 80% Load	1 Blade Server	2 Blade Server	3 Blade Server	4 Blade Server	5 Blade Server	6 Blade Server	7 Blade Server	8 Blade Server	9 Blade Server	10 Blade Server	11 Blade Server	12 Blade Server	13 Blade Server	14 Blade Server	15 Blade Server	16 Blade Server
Input Power	**722**	**935**	**1133**	**1332**	**1753**	**1949**	**2145**	**2343**	**2542**	**2743**	**2946**	**3150**	**3356**	**3563**	**3772**	**3981**
Input VA	737	954	1156	1359	1789	1989	2189	2391	2594	2799	3006	3214	3424	3636	3848	4062
BTU	**2462**	**3188**	**3862**	**4543**	**5979**	**6646**	**7316**	**7990**	**8669**	**9354**	**10045**	**10741**	**11443**	**12150**	**12861**	**13575**
Input Current	2.05	2.65	3.21	3.77	4.97	5.52	6.08	6.64	7.2	7.77	8.34	8.92	9.5	10.09	10.68	11.28
Input Current Per Cord	1.023	1.324	1.604	1.887	2.483	2.76	3.038	3.318	3.6	3.885	4.172	4.461	4.752	5.05	5.341	5.638
Airflow in CFM	87	112	136	160	202	225	247	270	282	304	326	349	372	380	402	425
Airflow in CMM	2.454	3.177	3.848	4.527	5.72	6.358	6.999	7.643	7.974	8.604	9.239	9.88	10.526	10.762	11.392	12.024
Power/Heat Load @ 80% Load	17 Blade Server	18 Blade Server	19 Blade Server	20 Blade Server	21 Blade Server	22 Blade Server	23 Blade Server	24 Blade Server	25 Blade Server	26 Blade Server	27 Blade Server	28 Blade Server	29 Blade Server	30 Blade Server	31 Blade Server	32 Blade Server
Input Power	**4703**	**4916**	**5114**	**5313**	**5734**	**5930**	**6126**	**6324**	**6523**	**6724**	**6927**	**7131**	**7337**	**7544**	**7753**	**7962**
Input VA	737	954	1156	1359	1789	1989	2189	2391	2594	2799	3006	3214	3424	3636	3848	4062
BTU	**16037**	**16763**	**17437**	**18118**	**19554**	**20221**	**20891**	**21565**	**22244**	**22929**	**23620**	**24316**	**25018**	**25725**	**26436**	**27150**
Input Current	2.05	2.65	3.21	3.77	4.97	5.52	6.08	6.64	7.2	7.77	8.34	8.92	9.5	10.09	10.68	11.28
Input Current Per Cord	1.023	1.324	1.604	1.887	2.483	2.76	3.038	3.318	3.6	3.885	4.172	4.461	4.752	5.05	5.341	5.638
Airflow in CFM	87	112	136	160	202	225	247	270	282	304	326	349	372	380	402	425
Airflow in CMM	2.454	3.177	3.848	4.527	5.72	6.358	6.999	7.643	7.974	8.604	9.239	9.88	10.526	10.762	11.392	12.024
Power/Heat Load @ 80% Load	33 Blade Server	34 Blade Server	35 Blade Server	36 Blade Server	37 Blade Server	38 Blade Server	39 Blade Server	40 Blade Server	41 Blade Server	42 Blade Server	43 Blade Server	44 Blade Server	45 Blade Server	46 Blade Server	47 Blade Server	48 Blade Server
Input Power	**8684**	**8897**	**9095**	**9294**	**9715**	**9911**	**10107**	**10305**	**10504**	**10705**	**10908**	**11112**	**11318**	**11525**	**11734**	**11943**
BTU	**29612**	**30338**	**31012**	**31693**	**33129**	**33796**	**34466**	**35140**	**35819**	**36504**	**37195**	**37891**	**38593**	**39300**	**40011**	**40725**
Power/Heat Load @ 75% Load	49 Blade Server	50 Blade Server	51 Blade Server	52 Blade Server	53 Blade Server	54 Blade Server	55 Blade Server	56 Blade Server	57 Blade Server	58 Blade Server	59 Blade Server	60 Blade Server	61 Blade Server	62 Blade Server	63 Blade Server	64 Blade Server
Input Power	**12665**	**12878**	**13076**	**13275**	**13696**	**13892**	**14088**	**14286**	**14485**	**14686**	**14889**	**15093**	**15299**	**15506**	**15715**	**15924**
BTU	**43187**	**43913**	**44587**	**45268**	**46704**	**47371**	**48041**	**48715**	**49394**	**50079**	**50770**	**51466**	**52168**	**52875**	**53586**	**54300**

Table 4 - Rack Power Observations

Server/Rack/Org Grouping	Racks	Number of servers (powered On)	Actual Power Usage (Watts)	Average Server Power Usage (Watts)	
Research Computing	I24, I26, I30, R14, R8	88	12,485	142	
Collocation Customers	R1, R2, R3, R4, R5, R6, R7, R8b, R9a, R10, R11, R12, R13	80	19,580	245	
ITS Owned	E25, E26, E27, E28, E31, E33, E34, E38, E39, E40, I25, I27, I28, I29, I38, I39, I42	130	37,895	292	
Totals		298	69960	235	(with research clusters)
		210	57,475	274	(without research clusters)

Table 5 - Summary of Initial data for calculations

Initial values for collocation customer, ITS, research, total DC, and DC research						
DC with research:						
Resources replaced per year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
# of servers to remove		**210**	**19**	**17**	**48**	**17**
Total CPU Integer processing power of removed servers		**1540.83**	**155.78**	**69.88**	**2754.39**	**268.54**
Total Power Reduction after removing servers		**49350**	**4465**	**3995**	**11280**	**3995**
DC without research:						
Resources replaced per year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
# of servers to remove		**137**	**19**	**17**	**17**	**17**
Total CPU Integer processing power of removed servers		**346.23**	**155.78**	**69.88**	**243.39**	**268.54**
Total Power Reduction after removing servers		**37538**	**5206**	**4658**	**4658**	**4658**
ITS initial data:						
Resources replaced per year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
# of servers to remove		**82**	**19**	**11**	**7**	**9**
Total CPU Integer processing power of removed servers		**224.5**	**155.78**	**43**	**94.39**	**82.66**
Total Power Reduction after removing servers		**23944**	**5548**	**3212**	**2044**	**2628**

Colo customer initial data:						
Resources replaced per year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
# of servers to remove		**55**	**0**	**6**	**10**	**8**
Total CPU Integer processing power of removed servers		**121.73**	**0**	**26.88**	**149**	**185.88**
Total Power Reduction after removing servers		**13475**	**0**	**1470**	**2450**	**1960**
Research cluster initial data:						
Resources replaced per year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
# of servers to remove		**73**	**0**	**0**	**31**	**0**
Total CPU Integer processing power of removed servers		**1194.6**	**0**	**0**	**2511**	**0**
Total Power Reduction after removing servers		**10366**	**0**	**0**	**4402**	**0**

Calculations and Costs

Power and BTU calculations:

Liebert Model VH267W 20-ton cooling units (or equivalent) are used to cool the data center. Each cooling unit uses a 5 horsepower (Hp) fan to deliver airflow and consumes 3.73 kW for airflow demand and 16.7 kW for thermal demand (liebert.com).

Total Heat Load = Room Area BTU + Windows BTU + Total Occupant BTU + Equipment BTU + Lighting BTU
Room Area BTU = Length (m) x Width (m) x 337
Total Occupant BTU = Number of occupants x 400
Equipment BTU = Total wattage for all equipment x 3.5
Lighting BTU = Total wattage for all lighting x 4.25

Spreadsheets used for Graphs

Datacenter including research computing:

Resources replaced per year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
# of servers to remove		210	19	17	48	17	55	5	6	14	2	17
Total CPU Integer processing power of removed servers		1540.83	155.78	69.88	2734.39	268.54	7762	1723	1665	5231	1167	10158
Total Power Reduction after removing servers		49350	4465	3995	11280	3995	14088	15024	17873	21006	21658	10706
Initial CPU Int of removed servers during 2009	1,541											

HP Blade Center	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Single HP BL495c Blade Server CPU Integer Power (January 2009)		132	191	278	402	584	846	1227	1779	2579	2740	5423
Usable CPU Integer value assuming max of 80% load on Blade Server		106	153	222	322	467	677	981	1423	2064	2992	4339
DataCenter Required CPU Int Load	4,789	5747	6897	8276	9931	11918	14301	17161	20594	24712	29655	35586
DataCenter Int Annual Growth		958	1149	1379	1655	1986	2384	2860	3432	4119	4942	5931
# of blades to purchase		59	3	6	13	2	12	5	4	4	3	4
Condition 1		0	3	6	0	2	0	5	4	4	3	4
Condition 2		0	0	0	13	0	12	0	0	0	0	0
Condition 3		0	0	0	0	0	0	0	0	0	0	0
Condition 4		0	0	0	0	0	0	0	0	0	0	0
Condition 5		59	0	0	0	0	0	0	0	0	0	0
Usable CPU Integer processing in Blade center		5,808	7,186	8,519	12,703	13,637	14,499	17,684	21,713	24,734	32,543	39,744
Total CPU Int Capacity in DC	4,789	10,597	11,976	13,308	17,493	18,475	16,540	18,911	23,144	26,798	34,737	44,084
# of HP Blades to add assuming each blade at 80% utilization		59	3	6	13	2	12	5	4	4	3	4
Total Blade Servers in DC for Customers		59	64	70	83	85	42	38	36	27	28	20
Total Power (W) required for BladeCenter(s) According to HP		14088	30012	47885	68023	90681	87198	61185	72606	58495	43968	38576
Power Value for 0-10 Servers		0	0	0	0	0	0	0	0	0	0	0
Power Value for 11-20 Servers		0	0	0	0	0	0	0	0	0	0	5313
Power Value for 21-30 Servers		0	0	0	0	0	0	0	0	6927	7181	0
Power Value for 31-40 Servers		0	0	0	0	0	0	9911	9394	0	0	0
Power Value for 31-40 Servers		14088	15924	17873	21038	21656	10705	0	0	0	0	0
Total BTUs Generated by DC		48041	102341	163287	232024	260837	243041	215891	175847	123613	113425	97747
BTU Value for 0-10 Servers		0	0	0	0	0	0	0	0	0	0	0
BTU Value for 11-20 Servers		0	0	0	0	0	0	0	0	0	0	18118
BTU Value for 21-30 Servers		0	0	0	0	0	0	0	0	23620	24016	0
BTU Value for 31-40 Servers		48041	54300	60946	71737	73854	36504	33790	31693	0	0	0
BTU Value for 31-40 Servers												
Total DataCenter Power Load for server hardware with migration to HP blade servers(Watts)	73,085	37,823	49,282	67,155	84,198	94,575	87,158	81,185	72,606	58,495	43,968	38,570
Annual Change in DataCenter power usage for Customer Hardware (Watts)		(35,262)	11,459	17,873	17,043	10,378	(7,418)	(6,013)	(8,579)	(14,111)	(14,527)	(5,398)
DataCenter power usage projection without virtualization (Watts)	73,085	79,384	91,213	104,899	120,410	138,362	158,977	182,665	209,862	241,195	277,087	318,372
Cooling												
Thermal Load on DataCenter (BTUs)	249,220	128,976	168,052	228,999	287,115	322,504	297,445	276,841	247,586	199,468	149,931	131,544
Thermal Load Reduction (BTUs)		120,243	(39,075)	(60,947)	(58,117)	(35,389)	25,159	20,604	29,254	48,119	49,537	18,387
Thermal Load Projection at 15% annual server growth without virtualization (BTUs)	249,220	286,354	329,020	378,044	434,373	499,094	573,400	658,905	757,082	869,887	999,503	1,148,426

Cost	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	5 Year Total Costs and Savings	10 Year Total Costs and Savings
Annual Electric cost for servers ($0.07/KWH) without virtualization	$ 44,815.72	$ 48,676.57	$ 55,933.82	$ 64,295.43	$ 73,840.98	$ 84,843.29	$ 97,448.54	$ 112,010.39	$ 128,699.71	$ 147,875.97	$ 169,909.49	$ 195,226.00	$ 327,539.84	$ 1,178,766.33
Annual Electric cost for servers ($0.07/KWH) with virtualization	$ 44,815.72	$ 23,187.06	$ 30,219.72	$ 41,179.45	$ 51,536.21	$ 57,994.00	$ 53,460.81	$ 49,782.64	$ 44,522.00	$ 35,860.13	$ 25,361.18	$ 23,654.90	$ 204,216.45	$ 438,476.02
Annual Savings in Server power reduction	$ -	$ 25,489.46	$ 25,713.90	$ 23,085.99	$ 22,210.77	$ 26,849.28	$ 44,015.12	$ 62,227.55	$ 84,177.71	$ 112,030.85	$ 142,348.31	$ 171,571.20	$ 123,345.39	$ 740,290.31
Electric cost for cooling without virtualization (BTUs/12000*0.3=1 ton of cooling=0.625 KWh)	$ 7,972.19	$ 9,160.05	$ 10,524.80	$ 12,097.11	$ 13,894.93	$ 15,965.33	$ 18,344.17	$ 21,077.45	$ 24,217.99	$ 27,826.47	$ 31,972.61	$ 36,736.53	$ 61,658.37	$ 221,813.60
Electric cost for cooling with virtualization (BTUs/12000*0.3=1 ton of cooling=0.625 KWh)	$ 7,972.19	$ 4,125.78	$ 5,375.74	$ 7,325.24	$ 9,184.41	$ 10,316.45	$ 9,511.00	$ 8,855.75	$ 7,919.54	$ 6,380.70	$ 4,790.08	$ 4,207.91	$ 36,327.72	$ 77,999.77
Cost Savings in cooling for servers	$ -	$ 5,034.28	$ 5,149.06	$ 4,771.87	$ 4,710.52	$ 5,648.88	$ 8,833.17	$ 12,221.70	$ 16,298.45	$ 21,445.77	$ 27,176.54	$ 32,528.62	$ 25,330.63	$ 143,813.83
# of physical ITS servers without virtualization (15% growth rate)	234	323	355	393	420	472	521	572	630	693	763	839		
# of HP Blade Servers with virtualization at 75% load	0	59	64	70	82	85	42	38	36	27	28	20		
Cost of current physical servers assuming $4000 average cost per server and 30% of existing servers are replaced annually	$ -	$ 194,340.00	$ 213,444.00	$ 236,788.40	$ 258,267.24	$ 284,003.96	$ 312,503.36	$ 343,753.70	$ 378,129.07	$ 415,941.97	$ 457,536.17	$ 503,289.79	$ 1,184,651.60	$ 3,595,787.66
Cost of HP Blade Servers including Chassis, network, and virtualization software ($16,242/blade server)		$ 485,861.78	$ 139,803.82	$ 134,142.08	$ 185,208.12	$ 91,023.84	$ 75,219.81	$ 36,821.64	$ 35,399.82	$ 29,387.66	$ 24,408.14	$ 29,406.22	$ 1,002,802.13	$ 1,228,314.91
Hardware cost		$ 433,547.42	$ 48,598.82	$ 66,879.28	$ 104,444.44	$ 37,775.76	$ 64,670.56	$ 28,948.80	$ 25,355.52	$ 21,335.52	$ 16,169.54	$ 21,559.52	$ 663,795.80	$ 836,271.96
Hardware Annual Maintenance		$ 2,248.00	$ 2,248.00	$ 2,810.00	$ 3,372.00	$ 3,372.00	$ 3,372.00	$ 3,372.00	$ 3,372.00	$ 3,372.00	$ 3,372.00	$ 3,372.00	$ 14,050.00	$ 34,282.00
# of Servers Added since		59	64	70	83	85	97	102	108	110	113	117		
# of blade enclosures added		4	0	1	1	0	2	0	2	0	0	0		
Software Cost (only for 22% of hardware)		$ 40,746.75	$ 47,614.80	$ 51,859.50	$ 63,440.35	$ 62,977.25	$	$	$	$	$	$	$ 264,483.45	$ 264,483.45
Software Annual Maintenance (only for 22% of hardware)		$ 9,280.53	$ 10,776.00	$ 11,786.25	$ 13,075.13	$ 14,311.58	$ 7,071.75	$ 6,339.25	$ 6,061.50	$ 4,346.13	$ 4,714.52	$ 3,367.50	$ 68,309.68	$ 92,265.50
Server Cost Savings		$ (291,821.78)	$ 134,432.68	$ 101,646.37	$ 35,001.13	$ 192,573.08	$ 237,285.05	$ 306,902.05	$ 347,053.05	$ 386,254.30	$ 432,102.00	$ 471,875.77	$ 181,831.48	$ 2,367,472.75
													$ -	
Total Savings due to virtualization of all servers in datacenter		$ (261,307.04)	$ 155,293.74	$ 129,590.17	$ 184,922.46	$ 225,071.24	$ 290,131.69	$ 381,381.29	$ 447,305.80	$ 519,806.93	$ 603,791.87	$ 678,973.58	$ 330,485.52	$ 3,251,576.69

Datacenter excluding research computing:

Total Datacenter without Research Computing	Initial	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	5 Year Total Costs and Savings	10 Year Total Costs and Savings
# of servers		137	19	17	17	17	16	2	2	2	2	2		
Total CPU Int		446.2	155.8	69.9	243.4	268.5	1112	333	555	805	1067	1692		
Total Power		17538	5206	4658	4658	4658	5981	4916	5313	5950	6324	7748		
Initial CPU Int of removed servers during 2009	446													
HP Blade Center		**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**		
Single HP BL495c Blade Server CPU Integer Power (January 2009)		132	191	278	402	564	846	1222	1779	2573	3740	5424		
Usable CPU integer value assuming max of 80% load on Blade Server		106	153	222	322	451	677	981	1423	2064	2992	4339		
DataCenter Required CPU Int Load	1,084	1301	1561	1873	2247	2697	3236	3884	4660	5592	6711	8053		
DataCenter Int Annual Growth		217	260	312	375	449	539	647	777	932	1118	1342		
# of blades to purchase		16	2	2	2	2	2	2	2	2	2	2		
Condition1		0	2	2	2	2	2	2	2	2	2	2		
Condition2		16	0	0	0	0	0	0	0	0	0	0		
Condition3		0	0	0	0	0	0	0	0	0	0	0		
Condition4		0	0	0	0	0	0	0	0	0	0	0		
Condition5		0	0	0	0	0	0	0	0	0	0	0		
Usable CPU Integer processing in Blade center		1,690	1,996	2,440	3,084	4,017	3,359	4,805	7,130	10,457	15,270	22,355		
Total CPU Int Capacity in DC	1,084	2,773	3,080	3,524	4,168	5,101	3,998	5,330	7,842	11,484	16,756	24,424		
# of HP Blades to add assuming each blade at 80% utilization		16	2	2	2	2	2	2	2	2	2	2		
Total Blade Servers in DC		16	18	20	22	24	10	10	10	10	10	10		
Total Power (W) required for BladeCenter(s) According to HP		3981	3852	14210	20140	26454	25226	23053	20483	17216	13715	13715		
Power Value for 0-10 Servers		0	0	0	0	0	2743	2743	2743	2743	2743	2743		
Power Value for 11-20 Servers		3981	4916	5315	0	0	0	0	0	0	0	0		
Power Value for 21-30 Servers		0	0	0	5930	6324	0	0	0	0	0	0		
Power Value for 31-40 Servers		0	0	0	0	0	0	0	0	0	0	0		
Power Value for 31-40 Servers		0	0	0	0	0	0	0	0	0	0	0		
Total BTU's Generated by BC		13575	30338	48435	68677	76657	69258	60494	49627	37416	37416	37416		
BTU Value for 0-10 Servers		0	0	0	0	0	9354	9354	9354	9354	9354	9354		
BTU Value for 11-20 Servers		13575	15763	18118	0	0	0	0	0	0	0	0		
BTU Value for 21-30 Servers		0	0	0	20221	21555	0	0	0	0	0	0		
BTU Value for 31-40 Servers		0	0	0	0	0	0	0	0	0	0	0		
BTU Value for 31-40 Servers														
Total DataCenter Power Load for server hardware with migration to HP blade servers(Watts)	56,716	23,161	22,871	26,184	25,456	31,122	25,226	23,053	20,483	17,256	13,715	13,715		
Annual Change in DataCenter power usage for Customer hardware (Watts)		(33,557)	(290)	3,313	1,272	5,666	(5,896)	(2,173)	(2,570)	(3,187)	(3,581)			
DataCenter power usage projection without virtualization (Watts)	56,718	59,817	68,730	78,070	90,737	104,257	119,791	137,640	158,148	181,712	208,787	239,897		
Cooling														
Thermal Load on DataCenter (BTUS)	193,406	78,979	77,990	90,107	100,445	106,126	86,021	78,611	69,847	58,979	46,769	46,768		
Thermal Load Reduction (BTUs)		114,429	989	(13,117)	(10,338)	(5,681)	20,105	7,410	8,764	10,868	12,211	-		
Thermal Load Projection at 15% annual server growth without virtualization (BTUs)	193,406	222,226	255,338	293,383	337,097	387,325	445,036	511,347	587,537	675,080	775,667	891,242		
Cost (Total Datacenter without Research Computing)														
Annual Electric cost for servers ($0.07/KWH) without virtualization	$ 34,779.48	$ 46,571.25	$ 47,145.05	$ 48,424.64	$ 55,639.01	$ 63,950.26	$ 73,455.87	$ 84,400.75	$ 96,976.51	$ 111,425.01	$ 128,028.48	$ 147,104.73	$ 246,819.59	$ 888,211.96
Annual Electric cost for servers ($0.07/KWH) with virtualization	$ 34,779.48	$ 14,192.13	$ 14,024.30	$ 17,282.43	$ 18,062.42	$ 19,064.01	$ 15,469.58	$ 14,135.10	$ 12,560.18	$ 10,605.91	$ 9,410.04	$ 8,410.04	$ 82,655.68	$ 152,246.52
Annual Savings in Server power reduction	$ -	$ 32,377.42	$ 28,120.53	$ 31,142.21	$ 37,577.49	$ 44,845.25	$ 57,987.28	$ 70,264.65	$ 84,416.33	$ 100,820.10	$ 119,618.44	$ 138,694.69	$ 164,163.90	$ 735,965.44
Electric cost for cooling without virtualization (BTUs/12000BTU=1 ton of cooling=0.526 KW)	$ 6,186.86	$ 7,108.71	$ 8,167.90	$ 9,384.92	$ 10,783.27	$ 12,469.98	$ 14,236.09	$ 16,357.27	$ 18,794.30	$ 21,594.88	$ 24,812.52	$ 28,509.58	$ 47,834.79	$ 172,139.62
Electric cost for cooling with virtualization (BTUs/12000BTU=1 ton of cooling=0.526 KW)	$ 6,186.86	$ 2,526.43	$ 2,494.79	$ 3,074.34	$ 3,213.09	$ 3,394.82	$ 2,751.68	$ 2,514.65	$ 2,234.31	$ 1,886.67	$ 1,496.05	$ 1,496.05	$ 14,703.48	$ 27,082.88
Cost Savings in cooling for servers	$ -	$ 4,582.28	$ 5,673.11	$ 6,310.58	$ 7,570.18	$ 8,995.16	$ 11,484.41	$ 13,842.62	$ 16,560.10	$ 19,708.21	$ 23,316.47	$ 27,013.53	$ 33,131.30	$ 145,056.74
# of physical IIS servers without virtualization (15% annual growth rate)	190	209	230	253	278	306	337	370	407	449	493	542		
# of HP Blade Servers with virtualization at 75% load	0	16	18	20	22	24	10	10	10	10	10	10		
Cost of non virtualized servers assuming $4000 average cost per server and 25% of existing servers are replaced annually	$	$ 167,200.00	$ 183,920.00	$ 202,312.00	$ 222,543.20	$ 244,797.52	$ 269,277.27	$ 296,205.00	$ 325,825.50	$ 358,408.05	$ 394,248.85	$ 433,673.74	$ 1,020,772.72	$ 3,098,411.13
Cost of HP Blade Servers including Chassis, network, and virtualization software ($13,247/blade server)		$ 165,833.08	$ 119,038.76	$ 92,523.76	$ 101,025.75	$ 108,127.76	$ 19,429.76	$ 15,431.76	$ 19,433.76	$ 15,435.76	$ 13,437.76	$ 19,439.76	$ 608,069.12	$ 724,677.68
Hardware cost		$ 120,514.08	$ 45,355.75	$ 10,779.76	$ 10,779.75	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 10,779.75	$ 197,909.12	$ 262,587.68
Hardware Annual Maintenance		$ 552.00	$ 1,104.00	$ 1,104.00	$ 1,104.00	$ 1,104.00	$ 1,104.00	$ 1,104.00	$ 1,104.00	$ 1,104.00	$ 1,104.00	$ 1,104.00	$ 5,058.00	$ 11,802.00
# of Servers Added since		16	18	20	22	24	26	28	30	32	34	36	$ 100.00	$ 286.00
# of blade enclosures added		1	1	0	0	0	0	0	0	0	0	0	$ 2.00	$ 2.00
Software Cost		$ 52,800.00	$ 59,400.00	$ 66,000.00	$ 72,600.00	$ 79,200.00	$ -	$ -	$ -	$ -	$ -	$ -	$ 330,000.00	$ 330,000.00
Software Annual Maintenance		$ 12,000.00	$ 13,500.00	$ 15,000.00	$ 16,500.00	$ 18,000.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 75,000.00	$ 120,000.00
Server Cost Savings		$ (18,693.08)	$ 64,871.24	$ 109,788.24	$ 121,517.44	$ 136,669.76	$ 249,847.51	$ 276,773.24	$ 306,391.74	$ 338,972.29	$ 374,811.09	$ 414,233.98	$ 412,703.60	$ 2,373,733.45
													$ -	
Total Savings due to virtualization of Customer hardware		$ 8,366.62	$ 98,614.89	$ 146,841.03	$ 166,665.11	$ 189,511.17	$ 319,319.20	$ 360,880.55	$ 407,368.26	$ 459,500.60	$ 517,746.01	$ 579,942.20	$ 609,998.81	$ 3,254,755.63

ITS Server Calculations:

Resources replaced per year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019		
# of servers to remove		82	19	11	7	9	9	2	2	2	2	2		
Total CPU Integer processing power of removed servers		224.5	155.78	43	94.39	82.66	1186	383	555	809	1167	1697		
Total Power Reduction after removing servers		23944	5548	3212	2044	2628	2542	2946	3355	3772	4733	2743		
Initial CPU Int of removed servers during 2009	225													
HP Blade Center		**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**		
Single HP BL495c Blade Server CPU Integer Power (January 2009)		132	191	278	402	584	846	1222	1779	2529	3745	5423		
Usable CPU Integer value assuming max of 80% load on Blade Server		106	153	222	322	467	677	981	1423	2024	2992	4339		
DataCenter Required CPU Int Load	600	720	864	1037	1245	1494	1793	2151	2581	3098	3717	4461		
DataCenter Int Annual Growth		120	144	173	207	249	299	358	430	516	620	743		
# of blades to purchase		9	2	2	2	2	2	2	2	2	2	2		
Condition 1		9	2	2	2	2	2	2	2	2	2	2		
Condition 2		0	0	0	0	0	0	0	0	0	0	0		
Condition 3		0	0	0	0	0	0	0	0	0	0	0		
Condition 4		0	0	0	0	0	0	0	0	0	0	0		
Condition 5		0	0	0	0	0	0	0	0	0	0	0		
Usable CPU Integer processing in Blade center		950	1,257	1,701	2,345	3,275	4,444	5,024	7,315	10,637	15,455	22,429		
Total CPU Int Capacity in DC	600	1,551	1,857	2,301	2,945	3,876	5,782	5,515	8,327	11,569	16,551	24,609		
# of HP Blades to add assuming each blade at 80% utilization		9	2	2	2	2	2	2	2	2	2	2		
Total Blade Servers in DC		9	11	13	15	17	10	10	10	10	10	10		
Total Power (W) required for BladeCenter(s) According to HP		3542	5483	6944	17516	17519	17520	17317	16704	15675	13715	13715		
Power Value for 0-10 Servers		3542	0	0	0	0	2743	2743	2743	2743	2743	2743		
Power Value for 11-20 Servers		0	2946	3356	8772	4703	0	0	0	0	0	0		
Power Value for 21-30 Servers		0	0	0	0	0	0	0	0	0	0	0		
Power Value for 31-40 Servers		0	0	0	0	0	0	0	0	0	0	0		
Power Value for 31-40 Servers		0	0	0	0	0	0	0	0	0	0	0		
Total BTU's Generated by BC		8569	18734	30157	43018	50386	49695	47606	44099	37405	37416	37416		
BTU Value for 0-10 Servers		8569	0	0	0	0	9354	9354	9354	9354	9354	9354		
BTU Value for 11-20 Servers		0	10045	11443	12861	16037	0	0	0	0	0	0		
BTU Value for 21-30 Servers		0	0	0	0	0	0	0	0	0	0	0		
BTU Value for 31-40 Servers		0	0	0	0	0	0	0	0	0	0	0		
BTU Value for 31-40 Servers														
Total DataCenter Power Load for server hardware with migration to HP Blade servers (Watts)	37,376	15,974	13,372	16,728	17,268	19,547	17,520	17,317	16,704	15,675	13,715	13,715		
Annual Change in DataCenter power usage for Customer hardware (Watts)		(21,402)	(2,602)	3,356	540	2,279	(2,027)	(203)	(613)	(1,029)	(1,960)	-		
DataCenter power usage projection without virtualization (Watts)	37,376	39,925	45,874	52,710	60,565	69,587	79,956	91,860	105,558	121,286	139,357	160,122		
Cooling														
Thermal Load on DataCenter (BTUs)	127,452	54,471	45,599	57,042	58,952	68,019	59,743	59,051	56,961	53,452	46,768	46,766		
Thermal Load Reduction (BTUs)		72,981	8,872	(11,444)	(1,910)	(9,067)	8,276	692	2,090	3,509	6,684	-		
Thermal Load Projection at 15% Annual server growth without virtualization (BTUs)	127,452	146,443	168,262	193,354	222,140	255,250	293,275	336,967	387,175	444,864	511,149	587,310		
													5 Year Total Costs and Savings	**10 Year Total Costs and Savings**
Cost														
Annual Electric cost for servers ($0.07/KWH) without virtualization	$ 22,918.96	$ 24,482.29	$ 28,130.15	$ 32,321.54	$ 37,137.45	$ 42,670.93	$ 49,028.90	$ 56,334.23	$ 64,728.00	$ 74,372.47	$ 85,453.07	$ 93,186.61	$ 164,742.35	$ 592,846.51
Annual Electric cost for servers ($0.07/KWH) with virtualization	$ 22,918.96	$ 9,795.26	$ 8,199.71	$ 10,257.61	$ 10,601.00	$ 12,231.50	$ 10,743.26	$ 10,618.79	$ 10,242.89	$ 9,611.91	$ 8,410.04	$ 8,410.04	$ 51,085.08	$ 109,122.01
Annual Savings in Server power reduction	$ -	$ 14,687.03	$ 19,930.44	$ 22,063.93	$ 26,536.45	$ 30,439.43	$ 38,285.63	$ 45,715.42	$ 54,485.11	$ 64,760.56	$ 77,043.03	$ 89,776.57	$ 113,657.28	$ 483,724.50
Electric cost for cooling without virtualization (BTUs)(12000BTU=1 ton of cooling=3.626 KW)	$ 4,077.02	$ 4,684.49	$ 5,382.48	$ 6,184.47	$ 7,105.95	$ 8,164.74	$ 9,381.29	$ 10,779.10	$ 12,385.19	$ 14,230.58	$ 16,350.94	$ 18,787.35	$ 31,522.14	$ 113,436.48
Electric cost for cooling with virtualization (BTUs)(12000BTU=1 ton of cooling=3.626 KW)	$ 4,077.02	$ 1,742.46	$ 1,458.63	$ 1,824.71	$ 1,885.79	$ 2,175.84	$ 1,911.10	$ 1,888.96	$ 1,822.09	$ 1,709.85	$ 1,496.05	$ 1,496.05	$ 9,087.44	$ 19,411.53
Cost Savings in cooling for servers	$ -	$ 2,942.03	$ 3,923.85	$ 4,359.76	$ 5,220.16	$ 5,988.90	$ 7,470.19	$ 8,890.15	$ 10,563.10	$ 12,520.74	$ 14,854.80	$ 17,291.18	$ 22,434.70	$ 94,024.95
# of physical servers without virtualization (15% annual growth rate)	119	131	144	158	174	192	211	232	255	281	309	340		
# of HP Blade Servers with virtualization at 75% load	0	9	11	13	15	17	10	10	10	10	10	10		
Cost of non virtualized servers assuming $4000 average cost per server and 20% of existing servers are replaced annually	$	$ 104,720.00	$ 119,192.50	$ 125,711.20	$ 139,382.52	$ 153,320.95	$ 168,652.61	$ 185,517.87	$ 204,069.65	$ 224,476.62	$ 246,924.28	$ 271,616.71	$ 639,326.07	$ 1,940,583.81
Cost of HP Blade servers including chassis, network, and virtualization software ($13,242/blade server)		$ 119,806.92	$ 55,902.76	$ 64,024.76	$ 72,106.76	$ 115,047.76	$ 19,422.76	$ 19,424.76	$ 19,426.76	$ 19,428.76	$ 19,430.76	$ 19,432.76	$ 426,868.96	$ 543,455.52
Hardware cost		$ 82,784.92	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 45,056.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 160,179.96	$ 224,858.52
Hardware Annual Maintenance		$ 562.00	$ 562.00	$ 562.00	$ 562.00	$ 1,124.00	$ 1,124.00	$ 1,124.00	$ 1,124.00	$ 1,124.00	$ 1,124.00	$ 1,124.00	$ 3,372.00	$ 10,116.00
# of Servers Added since		9	11	13	15	17	19	21	23	25	27	29	$ 65.00	$ 209.00
# of blade enclosures added		1	0	0	0	1	0	0	0	0	0	0	$ 2.00	$ 2.00
Software Cost		$ 29,700.00	$ 36,300.00	$ 42,900.00	$ 49,500.00	$ 56,100.00	$ -	$ -	$ -	$ -	$ -	$ -	$ 214,500.00	$ 214,500.00
Software Annual Maintenance		$ 6,750.00	$ 8,250.00	$ 9,750.00	$ 11,250.00	$ 12,750.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 48,750.00	$ 93,750.00
Server Cost Savings		$ (15,086.92)	$ 63,289.74	$ 62,706.44	$ 67,275.76	$ 38,273.20	$ 149,229.85	$ 166,093.11	$ 184,642.89	$ 205,047.86	$ 227,493.52	$ 252,183.95	$ 212,457.11	$ 1,397,148.29
													$ -	
Total Savings due to virtualization of Customer hardware		**$ 2,542.14**	**$ 83,143.53**	**$ 89,130.13**	**$ 99,032.37**	**$ 74,701.12**	**$ 194,985.67**	**$ 220,698.67**	**$ 249,691.10**	**$ 282,329.16**	**$ 319,392.35**	**$ 359,251.71**	**$ 348,549.09**	**$ 1,974,897.75**

Collocation Customer Server Calculations:

Resources replaced per year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019		
# of servers to remove		35	0	6	10	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Total CPU Integer processing power of removed servers		121.73	0	26.88	149	185.88	[illegible]	[illegible]	[illegible]	505	1157	[illegible]		
Total Power Reduction after removing servers		13471	0	1470	2450	1960	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Initial CPU Int of removed servers during 2009	[illegible]													
HP Blade Center		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019		
Single HP BL495c Blade Server CPU Integer Power (January 2009)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Usable CPU integer value assuming max of 80% load on Blade Server		106	[illegible]	[illegible]	[illegible]	467	673	[illegible]	1423	2064	[illegible]	4339		
DataCenter Required CPU Int Load	483	580	696	835	1,003	1203	1444	1733	2079	2495	2994	3592		
DataCenter Int Annual Growth		97	116	139	167	201	241	289	346	416	499	599		
# of blades to purchase		7	2	3	3	2	3	2	3	2	3	2		
Condition 1		7	2	2	3	2	3	2	3	2	2	2		
Condition 2		0	0	0	0	0	0	0	0	0	0	0		
Condition 3		0	0	0	0	0	0	0	0	0	0	0		
Condition 4		0	0	0	0	0	0	0	0	0	0	0		
Condition 5		0	0	0	0	0	0	0	0	0	0	0		
Usable CPU Integer processing in Blade center		739	1,045	1,489	2,133	3,067	4,497	5,077	7,338	10,690	15,507	22,492		
Total CPU Int Capacity in DC	483	1,223	1,529	1,973	2,617	3,550	4,933	5,368	8,080	11,712	17,009	24,662		
# of HP Blades to add assuming each blade at 80% utilization		7	2	2	2	2	2	2	2	2	2	2		
Total Blade Servers in DC		7	9	11	13	15	10	10	10	10	10	10		
Total Power (W) required for BladeCenter(s) According to HP		[illegible]	4587	7653	10989	14750	15359	15550	15357	14744	13715	13717		
Power Value for 0-10 Servers		2195	2542	0	0	0	[illegible]	2743	[illegible]	2743	2743	2743		
Power Value for 11-20 Servers		0	0	2945	3356	[illegible]	0	0	0	0	0	0		
Power Value for 21-30 Servers		0	0	0	0	0	0	0	0	0	0	0		
Power Value for 31-40 Servers		0	0	0	0	0	0	0	0	0	0	0		
Power Value for 31-40 Servers		0	0	0	0	0	0	0	0	0	0	0		
Total BTU's Generated by BC		[illegible]	15535	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37416	[illegible]		
BTU Value for 0-10 Servers		[illegible]	[illegible]	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
BTU Value for 11-20 Servers		0	0	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0		
BTU Value for 21-30 Servers		0	0	0	0	0	0	0	0	0	0	0		
BTU Value for 31-40 Servers		0	0	0	0	0	0	0	0	0	0	0		
BTU Value for 31-40 Servers														
Total DataCenter Power Load for Custom Hardware with migration to HP blade servers (Watts)	19,355	8,025	10,567	13,513	15,399	16,721	15,359	15,560	15,357	14,744	13,715	13,715		
Annual Change in DataCenter power usage for Custom Hardware (Watts)		(11,330)	2,542	2,946	1,886	1,322	(1,362)	201	(203)	(613)	(1,029)			
DataCenter power usage projection without virtualization (Watts)	19,355	19,987	22,965	26,352	30,315	34,836	40,026	45,930	52,843	60,716	69,753	80,158		
Cooling														
Thermal Load on DataCenter (BTUS)	66,001	27,365	36,033	46,079	52,511	57,019	52,374	53,060	52,367	50,277	46,768	46,768		
Thermal Load Reduction (BTUs)		38,635	(8,668)	(10,046)	(6,431)	(4,508)	4,644	(685)	692	2,090	3,509			
Thermal Load Projection at 15% annual server growth without virtualization (BTUS)	66,001	75,835	87,134	100,117	115,034	132,175	151,869	174,497	200,497	230,371	264,695	304,136		
													5 Year Total Costs and Savings	**10 Year Total Costs and Savings**
Cost														
Annual Electric cost for servers ($0.0799/KW-hr) without virtualization	$ 11,868.49	$ 13,253.94	$ 14,082.07	$ 16,180.30	$ 18,591.17	$ 21,361.25	$ 24,544.06	$ 28,201.15	$ 32,403.12	$ 37,231.18	$ 42,779.58	$ 49,152.65	$ 82,470.74	$ 296,781.54
Annual Electric cost for servers ($0.0799/KW-hr) with virtualization	$ 11,868.49	$ 4,920.93	$ 6,479.68	$ 8,286.17	$ 9,442.67	$ 10,253.32	$ 9,418.14	$ 9,541.39	$ 9,416.91	$ 9,041.02	$ 8,410.04	$ 8,410.04	$ 39,382.77	$ 93,620.31
Annual Savings in Server power reduction	$ -	$ 7,333.01	$ 7,602.39	$ 7,894.13	$ 9,148.50	$ 11,107.94	$ 15,125.94	$ 18,659.76	$ 22,986.21	$ 28,190.16	$ 34,369.55	$ 40,742.61	$ 43,087.97	$ 203,161.23
Electric cost for cooling without virtualization [illegible]	$ 2,111.24	$ [illegible]	$ 2,787.29	$ [illegible]	$ [illegible]	$ 4,228.09	$ [illegible]	$ 5,551.91	$ [illegible]	$ [illegible]	$ 8,467.25	$ 9,728.99	$ 16,323.61	$ 58,742.59
Electric cost for cooling with virtualization [illegible]	$ 2,111.24	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ 7,005.74	$ 16,653.96
Cost savings in cooling for servers	$ -	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ [illegible]	$ 9,317.87	$ 42,088.63
# of physical 1S servers without virtualization at 15% annual growth rate	41	79	36	[illegible]	104	119	126	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
# of HP Blade Servers with virtualization at 75% load	[illegible]	7	9	11	13	15	10	10	10	10	10	10		
Cost of non-virtualized servers assuming $4000 average cost per server and 20% of existing servers are replaced annually	$ -	$ 42,480.00	$ 68,[illegible]	$ [illegible]	$ 83,100.88	$ 91,[illegible]	$ 100,624.66	$ 110,687.[illegible]	$ 121,[illegible]	$ 133,931.41	$ 147,[illegible]	$ 162,[illegible]	$ 381,446.65	$ 1,1[illegible]
Cost of HP Blade Servers including Chassis, network, and virtualization software ($13,242/blade server)		$ 166,925.16	$ 47,900.76	$ [illegible]	$ 64,664.76	$ 22,136.76	$ [illegible]	$ 19,423.[illegible]	$ 19,424.76	$ 19,426.76	$ 19,428.76	$ 19,430.76	$ 340,740.70	$ 49[illegible]
Hardware Cost		$ 92,035.16	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 43,655.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 10,779.76	$ 115,174.20	$ 214,078.76
Hardware Annual Maintenance		$ 562.00	$ 562.00	$ 562.00	$ 562.00	$ 562.00	$ 1,124.00	$ 1,124.00	$ 1,124.00	$ 1,124.00	$ 1,124.00	$ 1,124.00	$ 2,810.00	$ 8,554.00
# of Servers Added Back		7	9	11	13	15	17	19	21	23	25	27	$ 55.00	$ 187.00
# of blade centers added		1	0	0	0	0	1	0	0	0	0	0	$ 1.00	$ 2.00
Software Cost		$ 23,100.00	$ 29,700.00	$ 36,300.00	$ 42,900.00	$ 49,500.00	$	$	$	$	$	$	$ 181,500.00	$ 181,500.00
Software Annual Maintenance		$ 5,250.00	$ 6,750.00	$ 8,250.00	$ 9,750.00	$ 11,250.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 41,250.00	$ 86,250.00
Server Cost Savings		$ (38,445.16)	$ 20,937.24	$ 19,898.04	$ 19,156.12	$ 19,370.31	$ 46,926.90	$ 91,264.57	$ 103,331.06	$ 114,504.67	$ 127,895.84	$ 142,625.27	$ 40,706.45	$ 666,255.56
Total Savings due to virtualization of Customer hardware		**$ (29,559.68)**	**$ 30,364.26**	**$ 29,320.76**	**$ 30,304.67**	**$ 32,862.28**	**$ 65,235.53**	**$ 113,808.74**	**$ 130,055.75**	**$ 148,455.78**	**$ 169,235.62**	**$ 191,601.71**	**$ 93,112.29**	**$ 911,505.42**

Research Computing Server Calculations:

Resources replaced per year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
# of servers to remove		73	0	0	33	0	60	2	3	30	2	12
Total CPU integer processing power of removed servers		1394.6	0	0	2513	0	7673	393	555	4374	1157	1201
Total Power Reduction after removing servers		10666	0	0	6402	0	10063	15605	17951	19657	19779	7331
Initial CPU Int of removed servers during 2009	3195											
HP Blade Center		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Single HP BL465c Blade Server CPU Integer Points (January 2009)		132	191	278	400	584	845	1222	1772	2574	3740	5424
Usable CPU integer value assuming max of 80% load on Blade Server		106	153	222	320	467	677	981	1423	2064	2992	4339
DataCenter Required CPU Int Load	3,705	4447	5336	6403	7684	9221	11065	13278	15933	19120	22944	27533
DataCenter Int Annual Growth		741	889	1067	1281	1537	1844	2213	2656	3187	3824	4589
# of blades to purchase		60	2	2	10	2	12	3	2	4	2	3
Condition1		0	2	2	10	2	0	3	2	4	2	3
Condition2		0	0	0	0	0	12	0	0	0	0	0
Condition3		0	0	0	0	0	0	0	0	0	0	0
Condition4		0	0	0	0	0	0	0	0	0	0	0
Condition5		60	0	0	0	0	0	0	0	0	0	0
Usable CPU Integer processing in Blade center		6,336	6,642	7,086	10,306	11,259	11,443	14,303	16,294	20,324	25,341	28,304
Total CPU Int Capacity in DC	3,705	10,042	10,348	10,792	14,011	14,945	13,472	14,739	17,036	20,588	26,568	31,458
# of HP Blades to add assuming each blade at 80% utilization		60	2	2	10	2	12	3	3	4	2	3
Total Blade Servers in DC		60	62	64	74	76	28	29	29	23	23	14
Total Power (W) required for BladeCenter(s) According to HP		15093	30599	46523	65190	84264	75802	68135	59546	47009	34057	30489
Power Value for 0-10 Servers		0	0	0	0	0	0	0	0	0	0	0
Power Value for 11-20 Servers		0	0	0	0	0	0	0	0	0	0	3503
Power Value for 21-30 Servers		0	0	0	0	0	7101	7327	7327	6125	6125	0
Power Value for 31-40 Servers		0	0	0	0	0	0	0	0	0	0	0
Power Value for 41-50 Servers		15093	15506	15924	18667	19074	0	0	0	0	0	0
Total BTU's Generated by BC		51496	104401	158641	222295	287504	258711	178023	159093	95245	97816	76960
BTU Value for 0-10 Servers		0	0	0	0	0	0	0	1	0	0	0
BTU Value for 11-20 Servers		0	0	0	0	0	0	0	1	0	0	17150
BTU Value for 21-30 Servers		0	0	0	0	0	24176	25018	25018	20891	20891	0
BTU Value for 31-40 Servers		51496	52875	54336	63694	65081	0	0	0	0	0	0
BTU Value for 31-40 Servers												
Total DataCenter Power Load for Custom Hardware with migration to HP blade servers (Watts)	14,765	19,495	35,001	50,925	69,592	84,264	76,302	68,135	59,546	47,009	34,057	30,489
Annual Change in DataCenter power usage for Custom Hardware (Watts)		4,727	15,506	15,924	18,667	14,672	(7,962)	(8,167)	(8,587)	(12,541)	(12,948)	(3,568)
DataCenter power usage projection without virtualization (Watts)	14,765	16,968	19,497	22,402	25,740	29,575	33,981	39,043	44,862	51,547	59,227	68,052
Cooling												
Thermal Load on DataCenter (BTUS)	50,359	66,478	119,353	173,694	237,309	287,340	260,190	232,334	203,052	160,292	116,154	103,967
Thermal Load Reduction (BTUS)		(15,119)	(52,875)	(54,301)	(63,654)	(50,032)	27,150	27,856	29,282	42,765	44,153	12,167
Thermal Load Projection at 15% annual server growth without virtualization (BTUS)	50,359	57,862	66,484	76,390	87,772	100,850	115,877	133,143	152,981	175,775	201,965	232,058

Cost	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	5 Year Total Costs and Savings	10 Year Total Costs and Savings
Annual Electric cost for servers ($0.07/KWH) without virtualization	$ 9,055.74	$ 10,409.04	$ 11,955.39	$ 13,736.75	$ 15,783.32	$ 18,135.27	$ 20,837.40	$ 23,942.20	$ 27,509.59	$ 31,608.31	$ 36,319.18	$ 41,729.59	$ 70,015.97	$ 251,961.47
Annual Electric cost for servers ($0.07/KWH) with virtualization	$ 9,055.74	$ 11,954.39	$ 21,462.61	$ 31,231.21	$ 42,675.61	$ 51,670.68	$ 46,788.39	$ 41,779.15	$ 36,513.61	$ 28,825.47	$ 20,885.75	$ 18,695.85	$ 158,988.66	$ 352,472.88
Annual Savings in Server power reduction	$ -	$ (1,545.29)	$ (9,507.22)	$ (17,496.46)	$ (26,892.29)	$ (33,535.42)	$ (25,950.96)	$ (17,836.95)	$ (9,004.02)	$ 2,785.07	$ 15,433.43	$ 23,033.74	$ (88,972.69)	$ (100,511.41)
Electric cost for cooling without virtualization (BTU's/3412 = KWH) * cooling efficiency of 0.65 KWH	$ 1,070.91	$ 1,570.94	$ 2,126.75	$ 2,543.01	$ 2,937.70	$ 3,226.09	$ 3,706.73	$ 4,159.01	$ 4,893.62	$ 5,622.79	$ 6,460.58	$ 7,423.31	$ 12,455.09	$ 44,821.01
Electric cost for cooling with virtualization (BTU's/3412)(0.65 KWH)	$ 1,070.91	$ 2,176.54	$ 3,817.95	$ 5,554.96	$ 7,591.12	$ 9,191.46	$ 8,323.11	$ 7,432.02	$ 6,495.34	$ 5,127.37	$ 3,715.98	$ 3,325.77	$ 28,282.33	$ 62,700.81
Cost savings in cooling for servers	$ -	$ (775.60)	$ (1,691.21)	$ (3,011.95)	$ (4,653.42)	$ (5,965.37)	$ (4,616.37)	$ (3,272.99)	$ (1,601.71)	$ 495.42	$ 2,745.60	$ 4,097.54	$ (15,827.20)	$ (17,879.81)
# of physical 1U servers without virtualization at 15% annual growth rate	133	114	126	139	152	167	184	203	223	245	270	297		
# of HP Blade Servers with virtualization at 75% load	0	60	62	64	74	76	28	29	29	23	23	14		
Cost of non-virtualized servers assuming $4000 average cost per server and 20% of existing servers are replaced annually	$ -	$ 91,520.00	$ 100,672.00	$ 110,739.20	$ 121,813.12	$ 133,994.43	$ 147,393.88	$ 162,133.26	$ 178,346.59	$ 196,181.25	$ 215,799.38	$ 237,379.31	$ 558,738.75	$ 1,695,972.43
Cost of HP Blade Servers including Chassis, network, and virtualization software ($13,242/blade server)		$ 462,807.80	$ 13,089.76	$ 13,091.26	$ 91,059.80	$ 13,665.76	$ 67,326.56	$ 19,073.51	$ 13,692.26	$ 14,466.52	$ 13,088.76	$ 19,081.64	$ 593,715.88	$ 751,282.76
Hardware Cost		$ 460,659.80	$ 10,779.76	$ 10,779.76	$ 88,174.80	$ 10,779.76	$ 64,628.56	$ 16,169.64	$ 10,779.76	$ 11,559.52	$ 10,779.76	$ 16,169.64	$ 581,030.88	$ 721,147.76
Hardware Annual Maintenance		$ 2,148.00	$ 2,248.00	$ 2,313.00	$ 2,813.00	$ 2,813.00	$ 2,813.00	$ 2,813.00	$ 2,813.00	$ 2,813.00	$ 2,813.00	$ 2,813.00	$ 12,364.00	$ 29,224.00
Total Servers Added since		60	62	64	74	76	88	91	93	97	99	102	$ 336.00	$ 906.00
# of blade enclosures added		4	0	0	-	0	3	0	0	0	0	0	$ 5.00	$ 5.00
Software Cost													$ -	$ -
Software Annual Maintenance													$ -	$ -
Server Cost Savings		$ (371,287.80)	$ 87,582.24	$ 97,647.94	$ 30,753.32	$ 120,328.67	$ 79,537.32	$ 143,062.63	$ 164,653.83	$ 171,714.73	$ 202,710.62	$ 218,297.67	$ (34,977.13)	$ 944,689.65
Total Savings due to virtualization of Customer hardware		$ (373,313.69)	$ 76,383.80	$ 77,045.63	$ (920.44)	$ 80,827.70	$ 49,249.98	$ 122,052.68	$ 154,058.10	$ 174,995.20	$ 220,290.65	$ 245,428.84	$ (139,777.01)	$ 826,298.44

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